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## CIVIL ENGINEERING.

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*Repairs and Renewal of the Roche-Bernard Suspension Bridge.* From a description given by M. NOYON, Engineer. Translated by J. BENNETT.

### PART SECOND.

(Continued from page 108.)

*Rebuilding of the Platform of the Bridge.*—After the fall of the platform, measures were immediately taken to provide for the travel across the Vilaine, in establishing a ferry upon the site formerly used by a barge, previous to the construction of the bridge. Nearly all the wood-work of the platform was recovered; but, excepting the beams, the principal pieces of carpentry were all injured and unfit for use; and as the shortness of the beams had contributed to the fall of the platform, it was determined to use new material.

The design of M. Lacroix, Eng., was approved by the administration, who ordered the work to be vigorously executed. Unfortunately, the proper wood could not be found in the yards of any commercial port, and as the Baltic was frozen, the work must have been deferred till the following spring, had not the marine department given permission to take all the pieces of large dimensions from the Arsenal of Brest.

Then the work went on, notwithstanding the bad season. The carpenters worked under a large shed raised near the approaches of the bridge. At the same time all the irons which had been saved, were repaired in a forge near the workshop, and new ones made when wanted. In three months, all was ready for laying the platform.

But this operation was retarded by another important one, which should have preceded this, but was suspended on account of the cold and rains. The coating of mastic and paint upon the cables had been torn away in many places; most of the ligatures had been bruised; some wires were injured or cut; so that this part of the suspension required a general renewal. Moreover, it was necessary to know the condition of the interior; so that arrangements had to be made for inspecting them throughout and repairing at the same time. All the ligatures were taken off, the painting scraped, and the bundles opened. Each wire was separately examined; those that were broken were joined; those that were loose were shortened; and after bringing them together, they were soaked in boiled linseed oil, thickened with an addition of litharge and lampblack. Then the ligatures were renewed, and the surface of the cables was covered with mastic, upon which were laid several coats of paint.

To attend to these details, a foot-bridge was made of the beams and joists of the old platform, and was suspended by iron rods, first to the two interior cables, and then to the two exterior; so that at each head of the bridge, one of the suspension bundles was completely free for work, while the other bore alone one side of the bridge.

Another matter delayed the establishment of the platform for a few days.

The friction rollers, as has been said, had slid upon their plates towards the sides of the porches; two of them bore upon the rim of the plate, and could not work. To restore them to the first position, the two cables of the same head had to be raised at the same time. The difficulty lay in the insufficiency of the means, it being impossible to instal a powerful apparatus, or to find a solid place of support.

After vainly trying great levers and an iron wedge moved by a strong screw, they finally used very tapering wood wedges, well tallowed, and with great difficulty succeeded in introducing them between the cables and masonry, and were five days in restoring the rollers to their true place.

The roadway was finished in less than a month, and on the 20th May, 1853, the bridge was ready for travel.

*Change in the System of Mooring Cables.*—The new galleries are 4·6 ft. wide and 6·5 ft. high. They have two masonry abutments against the rock, upon which rests a small brick arch, 4·3 ins. thick, with 6 ins. rise. The face of the walls is of rough hewn ashlar, except at the end cross gallery, where the cables embracing the masonry, it seemed best to line them with cut stone, so as to distribute upon a great surface the pressures borne by the pillow-blocks.

Upon this arch is a lining of Portland cement, arranged so as to form on each side of the axis, at their junction with the abutments,

canals to conduct the water filtering through the rock into vertical wells emptying outside the gallery. The oozings along and behind the masonry arrive through outlets into the cement gutters made at the foot of the abutments, through which they run to the discharge canals.

Between the arches and the top of the excavations, a space is reserved for a workman to pass from one side of the bridge to the other, and attend to whatever repairs may be needed.

The bottom of the gallery is covered with a masonry pavement, 7·9 ins. thick, resting upon the rock; the slopes on the sides are quite steep, but to have diminished them would have required a greater length and depth of excavation, and it was thought best to make only indispensable changes of the primitive profile to save expense; for this reason, the steps of the old galleries were preserved, though it would have been preferable to have had a uniform and continuous slope throughout.

The mooring galleries are now perfectly sound, and the arches staunch as possible, and no leaking has occurred.

Instead of passing down the vertical wells, the mooring cables are now a prolongation of the retaining without interruption, and so form with the suspension cables two continuous lengths, embracing upon each bank the masses of rock which constitute abutments of great solidity. To accomplish this, it sufficed to connect one by one, with new wires, all the strands of the up-stream bundles with the corresponding down-stream strands, by carrying the wires round the circuit of the cross galleries, and giving them a constant and appointed tension.

The operation of repairing the mooring cables was simple, but required care and precaution.

*Preliminary Details.*—In the first place, the covering pedestals (whose presence obstructed the passing of the new wires from one side of the bridge to the other) were removed; then the retaining bundles were unligatured between the towers, and 30 ft. inside of pedestals, so that the 16 elements, of which each was composed, were perfectly free, and grouped in two rows.

On the up-stream side were placed two dynamometers suspended by hooks upon an iron wire, parallel to the direction of the cables; on this wire the dynamometer could be slid at will. The first was attached to the cord of a windlass (No. 1), placed in the lowest part of the up-stream gallery; the second (No. 2), to that of another windlass (No. 2), placed upon the roadway, on up-stream side, 23 ft. in front of pedestal entrance. Each was provided with a jointed nipper, closing by means of a ring upon the index rod of tensions. A framed horse was placed between windlass No. 2 and pedestal, bearing a pulley, over which passed the cord of windlass (No. 2), and upon its upper cross-piece was made fast one of the ends of the wire supporting the dynamometers.

*Joining the Wires.*—With these arrangements, it was easy to effect the change in the system of mooring. A cut was made in one of the

down-stream bundles, within limits of points 5 ft. above and 33 ft. below face of pedestal, and after taking away the defective portion, to the extremity of a wire was joined that of a new wire, by a common ligature. This wire carried round to the up-stream side was seized at the other end by the nipper No. 2, and stretched by the windlass No. 2, till the dynamometer indicated the appointed tension. A strand taken from a corresponding element upon the up-stream side, was cut at any point within the above-named limits, and stretched by the windlass No. 1. The old and new threads were then held together by iron vices, and allowed the removal of the dynamometers whilst the second junction was made. This done, they were left to themselves, after taking away the vices and breaking off the useless ends of the ligatures.

The two strands of the retaining cables thus bound, were first kept isolated from the elements to which they belonged, so that no friction might impede the action of the windlass, and care also was taken to see that no obstacle was in the way of the new wire, especially in passing the grooves of the pillow blocks.

*Order of Taking up the Wires.*—The conditions of the work indicated the order of taking up the wires. Thus upon each side, the interior bundles, or those nearest to the mooring masonry, were first worked by the elements Nos. 1 and 2, adjoining the masonry; then Nos. 3 and 4 were taken up, and so on till the end. But after having repaired the first eight elements of the inner cable, they were left alongside of the other eight, to engage upon the half of the outer bundles, and for this reason:—

The previous tension to which each old and new wire was to be subjected, was not absolutely fixed. As it was important to prevent in the essential parts of the suspension, movements which would attend any alteration of the normal equilibrium, an endeavor was made to maintain for the restored wires their primitive tension, which the usual formulæ for the establishment of suspension bridges would give as 178 lbs. for each. But this figure derived from data, the principle of which, the suspension weight, being but approximately known, there were reasons to fear that it might differ from the truth. Now, if the given tension were too small, all the restored elements would have been too slack, and would have taken a greater sagitta in the parabolic part. The opposite would have been the case with too great a tension, and therefore the repair of the cables might produce a sensible rise or fall at their summits, and so in taking up completely one of the retaining bundles before touching the adjoining, it would be impossible to determine in the suspension curves of the same side the differences in level which might compromise the solidity of the yoke bands to which the platform rods were attached.

It was to avoid or lessen this inconvenience that the retaining cables were operated upon alternately.

No appreciable movement occurred either during or after the repair, so that the adopted tension differed but little from that of the old wires. A difference of level, 1·57 inches, which existed between the

bundles of the down-stream head, was even reduced one-half in diminishing by 6·6 lbs. the tension to be given to the wires of the highest bundle, before joining them to the new wires.

The operation was effected first upon the right bank, and then upon the left, instead of taking hold of both sides at once. The fear of having at any moment too great inequalities of tension between the untouched wires of the old cables and the restored portions, caused the adoption of this course. Besides the economy and good execution of the work, it was more convenient to use the same apparatus and workmen, instead of organizing a second gang.

*Distribution of the Ligatures.*—The ligatures, 1400 in number for each retaining cable, were distributed as uniformly as possible over a length of 33 ft. at the head of the pedestals. They were so completely lost within the bundles, that it is now difficult to distinguish their position; care was taken to cover them with a thick coat of red lead.

*Placing the Wires upon the Pillow-blocks.*—When the new wires crossed the pillow-blocks, they were placed in the grooves in regular and successive sheets, and were coated with red oxide of iron, or greasy substances, and care was taken to see that no friction or other cause should prevent the wires from receiving their proper tension.

*Preparatory Tension.*—Independently of this tension, which was fixed at 178·6 lbs., the wires were first subjected to another of 264·5 lbs., in order to overcome accidental resistances, and to destroy in part the bends existing in them.

*Dynamometers.*—The dynamometers, which were graduated in kilogrammes from 50 to 150, indicated the working of the windlasses, so as to have the normal tension; they were composed of three springs in a brass cylinder, 4 ins. diameter and 15·75 ins. long. The springs were fixed at one end to the bottom of the cylinder, and hooked by the other to a rod under the action of the tension, and carrying an index, which gave the effort exerted upon the rod by its position upon the graduated scale.

*Condition of the Wires of the Old Cables.*—The condition of the wires has shown the urgency of the operation; upon both banks and near the points where the sheetings merged into the cables (33 ft. inside of face of pedestals), 950, or about one-sixth of the whole number of wires, were completely eaten or cut up by rust.

In the cross galleries, at the point where the mooring cables bend round upon their pillows, the alteration was not so great, but existed for a great length. All the strands were more or less attacked, and the results of trials made upon 18 of them taken at hazard from the old bundles, shows that their force had diminished 7·13 kil. per square millimetre, or 10145 lbs. per square inch, or 139 lbs. per wire.

*Removal of the Old Cables.*—When all the strands of the two corresponding elements had been cut and then united by new wires, the ends of the elements forming the assemblage of sheeting and cables were easily removed outside of the galleries; but not so for the mooring bundles; they could not be taken away till after the repairs of all the cables, and then only in tearing them by scraps.

*Alteration of the Galleries.*—It was necessary to wait for the completion of the galleries (from face of pedestal to 65 ft. inside), before the repairs of the cables could be completely finished; for till then, they were inaccessible, and, even under the new cables, the space was so restricted that it was very difficult to extract the upper bed of the rock.

*Working Gang.*—Nine workmen sufficed for all the details of renewing the wires: four for making ligatures and attending to the dynamometers, two for service of windlasses, and three for carrying the wires and their stowage in the pillows. This gang could replace per day from 50 to 55 wires of the old cables. Four and a half months were consumed in joining the 5600 new wires with the 11,200 old ones.

*Net Cost.*—The expenses were divided into two classes: those for enlargement and change of mooring galleries, and those for repairs and change of cables; the first came to $6400, and the last to $5600.

These figures are considerable; but it must be remembered that the space is 656 ft. with a width of 20 ft., and that there are four cables containing in all 5600 wires; that the workmen operated in exceptional circumstances, and, by reason of the contracted space, could not effect more than a half of what could be done in better conditions; that the enlargement of the galleries required large excavations of great hardness, and that the blasting had to be done partially and with care to avoid injuring parts to be preserved; and, finally, that the parts of the newly-constructed cables, presented a length of 71 yards.

To render an exact account of the cost of a similar renewal in the case of a bridge of common dimensions, it would be best to use the following elementary data:—

A yard of wire, No. 19, weighs ·01408 lb., and the pound, including the linseed oil varnish, is worth 7¼ cents; the joining of a new wire with two old ones, costs from 7 to 8 cents; the purchase of the dynamometers and tension windlasses, their instalment, and the peculiar dispositions called for in the renewal of the cables, may be set at from $80 to $100. In France, many of the toll bridges have but 14·4 ft. width between handrails for a span of from 65 to 131 yds., and consequently the bundles contain only from 1600 to 2000 wires. If such cables are to be repaired, for a length of 32·8 yds., without a change in the system of mooring, the cost would be:—

| | |
|---|---|
| For 2000 new wires, 32·8 yds. long, weighing 9269 lbs., at 7·25 cents, . . | $ 672·00 |
| For rejoining 2000 wires, at 8 cents, . | 160·00 |
| For removing and renewing ligatures, recoating and painting, . . | 80·00 |
| Additional expenses, . . | 88·00 |
| | $1000·00 |

If necessary to modify the arrangement of mooring cables by substituting accessible galleries for wells, or by displacing the cables to make them embrace masonry abutments, there must be added a sum which, according to the case, may vary from $3000 to $4000.

These operations may be effected without interrupting the travel.

*Objection made to this Mode of Repairing.*—It was objected by some engineers that the accumulation of a great number of ligatures in a small portion of the cables, would diminish the strength of the latter, and that the fine wire of which they were made would be impaired sooner than the other parts of the cables, and in time get rusted, so as to fail in their duty.

When it is considered that these ligatures are placed in the same conditions with those that serve to join the cable wires, the inconvenience, if it exists, is reduced to a simple increase of the chances of rupture of all the ligatures; for, as regards resistance, it matters not whether they are uniformly distributed, or united at the same point. Now, the new made part has upon each bank a length of 65 to 75 metres, and the mean length of the bundles of wires, Nos. 18 and 19, vary between 70 and 80 metres, so that the renewal of the mooring cables does not increase the number of ligatures by more than 800 for the 5600 wires taken up, and as the whole number is nearly 26,250, for the whole length of the two cables the proportion of the chances of injury due to the ligatures is but $\frac{800}{26250}$ or $\frac{1}{32\frac{1}{8}}$. Moreover, these ligatures are less exposed to the effects of moisture than the rest of the cables, and are generally in good condition, even in the damaged parts. This is owing to coating them (at the time of making) with red lead or oil with litharge, which, lodging between the numerous circuits of the wires, adheres more strongly and lasts longer than upon the smooth surface of wires Nos. 18 and 19, besides remaining intact, while that which protects the other is often injured at the workshop, or whilst being put in place.

Besides, experiments made upon 18 strands taken from the old mooring cables, which had been left 18 months among the refuse of the workshop, show that on being stretched even to rupture, not one of the ligatures failed, even though the wires supported as a mean 1256 lbs.; one of them was only broken by a weight of 1500 lbs.

*The Two Supplementary Cables.—Arrangement of Cables.*—The two supplementary cables form a continuous skein, embracing on each bank the abutments against which the mooring cables rest, and containing each 1400 wires of ·014 sq. in. section.

Between the towers they describe above the old cables a parabolic curve with 47·89 feet sagitta, and their distance apart at the summit is 15¾ ins., and only 3½ at the ends. Beyond the towers they follow the same line with the retaining and moving cables, midway, and nearly at the same level; however, at their passage over the upper suspension roller, or that opposite the river, they are directly applied upon the sheets of cables, and only are independent at 19·5 ft. from the axis of the towers.

These dispositions, demanded by local circumstances and by the imposed obligation of preserving the agency of existing works and of respecting the forms and proportions of the masonry, are not without their faults. It would have been better had the old and new cables been equidistant throughout the parabolic curve; but as, near the

porches, their separation could not exceed 5½ ins., on account of the smallness of the openings which they penetrate, and as in so small a space there would be difficulties in removing and replacing the rods, whose forms had to be changed for suspension upon supplementary cables, they were obliged to relinquish the parallelism. On the other hand, it is to be regretted that the want of space did not allow a complete independence of the new cables from the others, for their overlaying causes considerable frictions which have sensibly constrained the displacements and reactions, which should be produced in the supplementary cables when charged with their load. This circumstance, though foreseen, but whose influence could not be appreciated because the change in the system of primitive suspension would necessarily occasion in the old and new cables inverse movements, the one independent, the other simultaneous; this circumstance, I say, prevented an exact determination of the position to be assigned to the supplementary cables when they were entirely free; so that the ultimate rise, which has been fixed at 48·21 ft., was but 47·89 ft., a difference of $3\frac{9}{10}$ ins.

*Suspension Rods.*—The rods of the supplementary cables only differed from the others in having a hook instead of an eye at the upper ends, embracing the new cable and fastened with wire No. 12.

*Cast Iron Bolsters.*—The new cables are separated from the old at the origin of the suspension curve by cast iron bolsters of an oval form and 3·28 ft. long. They rest upon the sheetings of the primitive cables at the site of the lower friction roller with an intervening layer of very thick mastic. Care was taken to give the most suitable form to the face of contact, and the relief of the sheetings was obtained by a lead plate, from which the moulds were made for each of the bolsters.

The cables were made in their place, the wires being left free, so that the regulating curve not being deranged, it was easy to appreciate the coincidence of each wire with those already in place. For the same reason the framed horses generally used to support the parts between the towers and mooring masonry were dispensed with.

*Various Details.*—This operation called for the removal of the upper portion of the porches, the openings for the passage of the old cables not being large enough for the introduction of a bundle of wire. The cut stone was deposited one side or in the chamber above the arches.

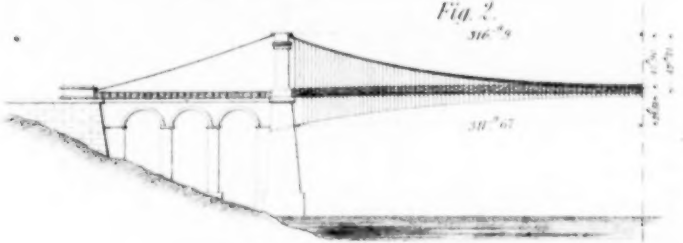
The moving of the wires from one bank to the other was effected upon the bridge, but the porches could not be turned, because the wires would be involved between the towers and the first rods, and so they were raised directly upon the porches.

Upon each bank, was placed above and corresponding with the sheetings of the old cables a windlass upon a frame, whose cord passed through a movable ring, fitted to the end of a wood swipe made to turn upon a horizontal axis in a vertical plane parallel to the direction of the cables; to this cord was suspended a lead cylindrical counterweight with a diameter greater than the ring.

To raise the wire, one end was attached to the counter weight, which in turning the winch is stopped by the ring, thus causing the bar to

Fig 1

Fig 2.



Elevation of one half of Bridge

Fig 3

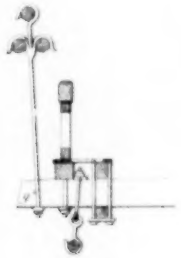


Fig 4

mode of fixing counter cables upon central beams

Fig 5.

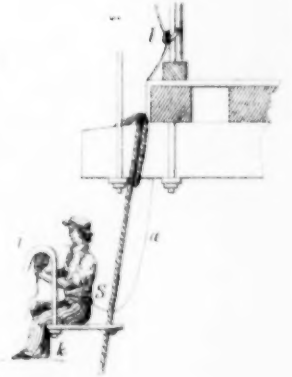


Fig 6.

describe a quarter-circle and to pass from its horizontal position a little beyond the vertical, when by turning the winch in the opposite direction, the counter weight falls drawing the wire with it to the level of road-way. While the windlass is at work, the other end of the wire is united to the last hank unwound upon the other side of tower.

To diminish the frictions which might obstruct the separate movements of the new cable, the bolsters and sheetings should be well tallowed before laying on the wires. Each layer of wire is also to be covered with the same material.

When all the wires are laid on, they are brought together and soaked in linseed oil thickened with a small quantity of litharge and lamp-black; then, being bound by ligatures of wire No. 12 distributed with a space between them equal to their length, which is 11·8 ins., they are lined with a layer of thick mastic and three coats of paint.

*Previous Tension.*—When a wire is stretched for the first time, under a given weight, it experiences an elongation, which does not completely disappear, on becoming free; for loads between 2 and 24 kilog. per square millimetre, or from 2845 to 34150 lbs. per square inch, the permanent elongation is about $\frac{1}{3}$ of the primitive. Now the old cables, having experienced the transient tension of the test load, the new should be found in the same conditions, or subjected to a tension of 16·5 kilog. per square millimetre (23478 lbs. per square inch) or 330 lbs. per wire. For this purpose each wire, through the action of a windlass at both sides of the bridge, is made to describe the same curve as that of one (Plate III., Fig. 1, *a b c*) invariably fixed between the porches, and whose rise was determined so that under its own weight it would be sollicited by a horizontal force of 330 lbs.

The rise was deduced from the formula

$$\text{R} = \frac{p\,h^2}{2\,f\cos.\,a}, \text{ from which we have } f = \frac{p\,h^2}{2\,\text{R}\cos.\,a};$$

$$\text{now } \cos.\,a = \frac{1}{\sqrt{1 + \text{tang.}^2\,a}} = \frac{1}{\sqrt{1 + \left(\frac{2f}{h}\right)^2}};$$

$$\text{consequently, } f = \frac{p\,h^2}{2\,\text{R}}\sqrt{1 + \left(\frac{2f}{h}\right)^2}.$$

A relation which finally gives

$$f = \frac{p\,h^2}{2\sqrt{\text{R}^2 - p^2\,h^2}}.$$

Substituting in this expression $h = 316{\cdot}93$ ft., R = 330 lbs., and $p = 0{\cdot}04704$ lbs. per running foot of wire No. 19, we have for the rise of the indicating wire 7·2 ft.*

Thus prepared, the two supplementary bundles present in their provisional position a perfect regularity, and the summits of the curves are upon the same horizontal line. This is a new proof of the advantage of making the cables in place; this system being as easily and simply applied in small as in great spans, while the raising of the con-

* The author gives $f = 2{\cdot}65$ m., which is erroneous; his data are $h = 96{\cdot}6$ m., R = 150 k., and $p = 0{\cdot}070$ k. per running metre. The curve, which is a catenary, is treated as a parabola.

stituent elements of cables for spans of more than 100 yards presents some difficulties, and the regulation of the different elements is not always attended with the desirable precision.

*Working Gangs and Cost.*—Independently of two agents whose special duty was to look after the perfect coincidence of the wires, there were 15 cablers or workmen who placed, per day, from 33 to 40 strands upon each head of bridge, that is to say, 31473 running yards of wire with a weight of 4411 lbs.

The daily wages of all these workmen came to $8·00; so that the laying of the cable came to 0·18 cents per pound. This operation, without accounting for the special fixtures, would have cost double had the cables been made elsewhere.

*Provisional Sagitta.*—Before making the supplementary cable, it was important to determine precisely the provisional position to be given it, so that under a permanent load of $\frac{1}{3}$ of that borne by the two old cables on same side of bridge, it should take its definitive position in respect to the latter; in other words, to determine the sagitta of the wire which should regulate the placing of all the strands of the additional cable.

As this is an interesting matter, we give the steps by which it was resolved.

The rise was first assumed at 45·93 ft. (that of the cables being 49·21 ft.); then to verify it, it was left to find by what quantity it must be increased, if the regulating wire is loaded, for each running foot of its horizontal projection, with a weight equal to that primitively borne by each of the suspension wires.

The known relation* $$\left(\frac{2f}{h}\right)^2 = 6\left(\frac{c-h}{h}\right)$$

which may be written under the form

$$f = \tfrac{1}{2}\sqrt{3h\,(2c - 2h)} \qquad (u)$$

which gives the sagitta $f$ of a parabolic curve in function of its length $2c$ and of its chord $2h$, enables us to determine the variations of the rise corresponding with those of the curve.

On the other hand, if a wire such as $a\,k\,c$, with a length $l$, is loaded with a weight $p$ per running foot, in the part between the points of support, it experiences an elongation $a$, resulting from the horizontal tension Q, due to the load, and to the change in form of the catenaries $m\,n\,p$, $m'\,n'\,p'$, whose length diminishes, while the parabolic arc has an equal increase (Plate III., Fig. 1).

This elongation is expressed by the formula:

$$a = \frac{Q\,l}{E\,S} + \frac{2\,\sigma^2\,a^3\cos.\,\omega}{24\,q^2}\left(1 - \frac{\sigma^2}{(\sigma+p)^2}\right) \qquad (v)$$

in which:

$\sigma$ = the weight per running foot of wire No. 19 = 0·04704 lbs.
$s$ = section of the same wire = 0·0000979 square foot.
$a$ = horizontal distance $o\,x$ between the ends of the retaining cables = 196·85 ft.

* Memoire de Navier sur les ponts suspendus, 2d Edition, p. 92.

Cos. $\omega = 0{\cdot}30$.

$\text{E}$ = co-efficient of elasticity = 4507552379 lbs. per sq. ft.

$\text{Q}$ = horizontal tension of each wire = $\dfrac{p\,h^2}{2f}$.

$q$ = tension of regulating wire under its own weight = $\dfrac{\sigma\,h^2}{2f}$.

Performing the calculation indicated in the expression $(v)$ in substituting for $h$ 316·93 ft., 1246·74 for $l$, and 0·14112 lbs. for $p$, we have

$$a = 0{\cdot}4352 + 0{\cdot}1594 \times {\cdot}9375 = 0{\cdot}5846.$$

And as the value $2c$, corresponding to a rise $f = 45{\cdot}93$ ft. is

$$2c = 2h\left(1 + \frac{2f^2}{2h^2}\right)^* = 642{\cdot}72 \text{ ft.}$$

it follows that in putting $2c + a = 643{\cdot}28$ ft. instead of $2c$ in the formula $(u)$ we obtain the length $\text{P} = 47{\cdot}40$ ft. of sagitta which the standard wire should take under the load $p$.

The space between the old and new cables having been fixed at 0·98 ft., this result shows that the provisional sagitta should be

$$49{\cdot}21 \text{ ft.} - (0{\cdot}98 + 1{\cdot}47) = 46{\cdot}76 \text{ ft.}$$

As, however, the preceding calculations have taken no account of the frictions of the wires upon their points of support, and as the formulæ rest upon hypotheses whose correctness has only been verified in certain limits, it seemed best by direct experiment to see if absolute confidence could be put in the indications of theory.

Consequently a wire No. 19 was stretched from $h$ to $g$ (Plate III., Fig. 1), describing the line $h\,n'\,a\,e\,c\,g$, loaded in the portion $a\,e\,c$ with a uniform weight, equal to that borne by each wire of the old cables; then, fixing fast the end $h$, it was stretched so that its summit $e$, being 0·98 ft. above the middle of the suspension cable, the two parts $h\,n'\,m'$ and $m\,n\,g$ should describe the same curves as the lower generatrices of the retaining bundles.

The wire being fastened at $g$, its load was removed. Its primitive form was changed, and the summit $e$ rose 1·67 ft., while the catenaries $m\,n\,p$, $m'\,n'\,p'$, were lowered beneath the retaining cables. This operation, many times repeated upon both sides of the bridge, always gave the same result to within from ·39 to ·78 of an inch.

Moreover, the wire when in the position $a\,k\,c$ was loaded with the same weight, and each time returned exactly to the position $a\,e\,c$.

The accordance of facts with theoretical deductions, and the consideration that the sagitta of a catenary (like that assumed by the supplementary cables during their construction) is shorter than that of a parabolic arc of the same length, caused the adoption for the regulating curve, of that described by the wire of experiment, and the provisional sagitta to be fixed at 49·21 ft. — (0·98 + 1·67) = 46·56 ft.

These operations were conducted on the supposition that the load of each new cable was equal to that borne by each old cable, while in

* The original has $\left(1 + \frac{2f^2}{3p^2}\right)$, probably a misprint.

reality it was but $\frac{2}{3}$ of it, and as within the limits considered, the elongations of sagitta may be regarded as proportional to tensions $\frac{2}{3}$ of the space $e\,k = 1{\cdot}67$ ft., or 1·115 ft. was taken for the lowering of the summit of the additional cable.

But at the same time, the inverse movement of the other cables was to be accounted for when they were relieved of $\frac{1}{3}$ of their primitive load, and the rise of their summit was supposed to be $\frac{1{\cdot}67}{3} = 0{\cdot}556$ ft.; so that the old and new cables would be $1{\cdot}115 + 0{\cdot}556 = 1{\cdot}67$ ft. apart.

(To be Continued.)

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For the Journal of the Franklin Institute.

*Iron Girder Bridge for the Boston and Worcester Railroad, over Watertown Road, in Brighton;* built by Wm. Adams & Co., Boston. By EDWARD S. PHILBRICK, C. E.

Though this structure differs in many of its details from any bridge of the kind hitherto constructed, the same ratio was used in the proportioning of the metal to the strains incurred as in other similar English and American structures, viz: a maximum tensile strain of four and one-half tons, and a compressive strain of four tons per square inch of section, incurred by a live load of one ton per lineal foot of track.

It consists substantially of three girders of the **I** form, supporting on their tops a floor and double-track railway, the girders being braced against each other in a thorough and rather peculiar manner.

The span is eighty-six feet and ten inches between bearings, approaching the limit where a tubular form would be preferable to a series of separate girders, and therefore requiring a degree of strength unusual in the **I** form of girder. The middle girder, having sometimes to support two trains at once, should they chance to meet on the bridge, is made proportionally strong and rigid, as fully proved by the test load, described below.

The great obliquity of the bridge (there being an angle of only 21° 30′ between the tracks and the abutments), while largely increasing the length and cost of both masonry and superstructure, is an advantage when compared with right-angled bridges of similar span, because each girder is here supported laterally by the abutment itself throughout one-third of its length.

The horizontal members at the top and bottom of the girders, devoted to resisting the compressive and tensile forces respectively, are all two feet in width, varying in thickness to conform to the strains to which they are subject. Their joints are spliced with plates of the same width, on both sides. They are attached to the vertical sheets or *web* by a four by four inch (4″ × 4″) angle iron on each side of the latter, passing along the centre of the horizontal plates. The joints of these angle irons are also spliced with a patch of similar form.

All abutting joints are accurately planed, as well as all sides of the sheets forming the *web*.

The sheets of the web of each girder are $\frac{3}{8}$ths and $\frac{7}{16}$ths of an inch thick, seven and a half feet high, and six feet three inches in width between joints. These vertical joints are abutted and covered by a batten, 8 inches wide on each side, and secured by a double row of rivets. Outside of these battens, on each side, is a vertical angle iron with a base of three inches, and a projecting flanch of six inches width, secured by the same rivets with the battens. Each end of these angle irons is bent out like a knee and attached by two rivets to the top and bottom members of the girder. In the middle of each sheet, or midway between these kneed ribs, is another vertical angle iron on each side, of the same dimensions, to check the vibration of the sheets, the ends of these being off-set and riveted through the horizontal angle irons which form the connexions between the vertical member or *web* and the horizontal plates at top and bottom.

The method usually adopted for joining these web-plates to each other in other plate-iron bridges, is to place a **T** iron on each side of the joint, the head of the **T** forming the batten, and the stem forming the rib. Having found these **T** irons beginning to split in a number of English bridges, owing to the weakness of the iron along the junction of the head and stem of the **T**, and finding no **T** iron of sufficient strength rolled in this country or to be obtained from England at a moderate cost, I preferred the arrangement described above, which the event has proved to be a decidedly stronger joint than the English one, and, at the same time, a cheaper one in our market.

As the tracks lie above the girders, ample opportunity is afforded for diagonal bracing between them, to maintain their perpendicularity and check vibration.

The ordinary mode of applying this bracing and that practised by English and Canadian engineers, is to attach at intervals of about 10 feet diagonal strips of plate-iron to the vertical ribs, crossing each other like the letter **X**, and riveted together at their intersection. But the height of our girders being unusually great ($7\frac{1}{2}$ feet), as well as the horizontal distance between them (11 feet), these braces might flap and vibrate under express trains to such an extent as to bring undue strain upon their attachments and render them nearly useless. To obviate this, I formed each brace of two pieces of plate-iron, six inches wide and three-eighths of an inch thick, connected at right angles to each other by a $1\frac{1}{2}$ inch angle iron riveted to each, giving a section similar to an angle iron, six inches wide on each side of the angle. As the two members of the **X** are placed back to back, they are riveted together at their intersection. In order to get the strongest available attachment between these braces and the vertical ribs of the girders, that half of each brace which does not lie in a vertical plane was heated at the ends and each end twisted 90°, allowing it to be attached to the ribs alongside the other strip, with the plane of which it here coincided. The result has been fully satisfactory, for the passage of heavy trains at high speed produces far less vibration

than in many similar bridges which I have had the opportunity to examine, in this country, and in England and France.

The rivets are, with a few exceptions, all of one inch diameter, being heated and headed in the usual manner.

The rivet-holes were all *drilled*, being, as I believe, the first case of the kind in a work of this size. It can hardly be doubted that drilling secures a cleanness of cut, if not an accuracy of position, unattainable by punching. The drill neither disturbs the fibre of the iron near the hole, nor bends or stretches the plates like a punch: circumstances which often render it difficult for punched plates to be accurately fitted to each other, or to have that exact correspondence of holes which is indispensable to a first-rate joint.

This bridge is to be subject to a traffic of some forty-five trains daily, many of which trains weigh 400 tons. Previous to opening it to the traffic, it was tested as follows:

A large pile of iron rails was distributed over the floor, and a train placed on each track, weighing in all 159·3 gross tons. The deflections were carefully observed at the centre of each girder, the load then removed and a second observation taken, after which the load was replaced and again removed, with two more observations. The first loading produced a permanent set of 0·26 inches, a considerable portion of which may doubtless be attributed to the bearings on the abutments, where a white oak cushion, four inches thick, was interposed between the iron and masonry. The second loading of the bridge brought the girders down to exactly the same point as the first, the deflections being given below with the loads upon each girder. On removing the load, these deflections disappeared entirely.

| | Tons load. | Deflection. |
|---|---|---|
| North girder, . . | 37·15 | 0·39 inches. |
| Centre " . . | 79·65 | 0·33 " |
| South " . . | 42·50 | 0·45 " |

The unequal distribution of the load upon the north and south girders was due to the different weight of the engines placed on the two tracks, a difference which was not intended, but which served to show how nearly the deflections vary with the weights producing them, proving the great uniformity of the workmanship in the three girders, while the rigidity of the centre girder is shown to be fully equal to its double duty.

The materials used in this bridge were entirely of American manufacture. Before determining on the kind of plate-iron to be used, I availed myself of the kindness of Capt. Rodman of the U. S. Arsenal at Watertown, and the excellent apparatus under his charge, to test a variety of samples of boiler plate, with a view of comparing both their ultimate tensile strength and their extensibility when subjected to a tension increased by certain known degrees at will. I give the results of these experiments in the annexed tables, with a summary description of the kind of iron of which each sample was composed. The great uniformity of the lower grade of iron (3d experiment), together with its great tensile strength, authorized its use in our bridge wherever it could be introduced without change of form. Wherever

such change is required, however, I could not recommend it, as in the case of steam boilers, &c.

1st Experiment.—*Three pieces from same sheet.*

| Tensions per Square Inch. | First piece. | | Second piece. | | Third piece. | |
|---|---|---|---|---|---|---|
| | Elongations. | | Elongations. | | Elongations. | |
| | While under tension. | After tension was removed. | While under tension. | After tension was removed. | While under tension. | After tension was removed. |
| 5,000 lbs. | ·00034 | ·00013 | ·00020 | ·00001 | ·00020 | ·00000 |
| 10,000 | ·00060 | ·00015 | ·00033 | ·00002 | ·00046 | ·00002 |
| 15,000 | ·00079 | ·00018 | ·00058 | ·00003 | ·00073 | ·00006 |
| 20,000 | ·00091 | ·00020 | ·00087 | ·00019 | ·00113 | ·00020 |
| 25,000 | ·00119 | ·00036 | ·00196 | ·00097 | ·00226 | ·00126 |
| 30,000 | ·00161 | ·00066 | ·01269 | ·01132 | ·01234 | ·01126 |
| 35,000 | ·00974 | ·00846 | ·03942 | ·03742 | ·02856 | ·02732 |
| 40,000 | ·03694 | did not recover | ·10942 | broke. | ·05060 | ·05060 |
| 43,580 | ·10800 and broke. | | | | broke at 42,800 lbs. pr in. | |

Note.—The elongations in all these tables are expressed in terms of the part measured, which was a strip of the plate 10 inches long, planed to a uniform section of about half a square inch; *i. e.* the first piece in the above experiment stretched about ·1 of its length before breaking, and bore a tension of 30,000 lbs. per inch, with a permanent elongation of only two-thirds of ·001 of its own length, &c., while the second piece stretched ·01 of its length by the same tension. A great part of the differences in the initial elongations may be attributed to the imperfection of the alignment of the bearings by which the specimens were attached—a difficult thing to avoid.

The iron used in this first experiment was from charcoal blooms entirely, known in the market as "best flanch iron," being warranted to turn flanches for boiler heads, &c., without cracking. The elasticity and strength under direct tension did not appear to be sufficiently superior to the iron used in the third experiment to warrant the difference in price, when used for purposes where no change of form was required. The specifications for our bridge called for this kind of iron, however, in cases where the form of plates was changed, the inferior grades not being able to endure such change without prejudice.

2d Experiment.—*Three pieces from same sheet.*

| Tensions per Square Inch. | First piece. | | Second piece. | | Third piece. | |
|---|---|---|---|---|---|---|
| | Elongations. | | Elongations. | | Elongations. | |
| | While under tension. | After tension was removed. | While under tension. | After tension was removed. | While under tension. | After tension was removed. |
| 5,000 lbs. | ·00016 | ·00001 | ·00016 | ·00002 | ·00023 | ·00001 |
| 10,000 | ·00038 | ·00002 | ·00035 | ·00004 | ·00047 | ·00003 |
| 15,000 | ·00059 | ·00003 | ·00054 | ·00004 | ·00063 | ·00004 |
| 20,000 | ·00084 | ·00007 | ·00076 | ·00004 | ·00082 | ·00005 |
| 25,000 | ·00112 | ·00016 | ·00101 | ·00011 | ·00123 | ·00017 |
| 30,000 | ·00317 | ·00209 | ·00216 | ·00110 | ·00211 | ·00089 |
| 35,000 | ·01920 | ·01791 | ·02746 | ·02646 | ·01965 | ·01801 |
| 40,000 | ·02488 | ·02346 | broke at 40,100 lbs. pr in. | | broke at 39,900 lbs. pr in. | |
| 43,444 | broke. | | | | | |

The iron in this experiment was made from a mixture of charcoal blooms and blooms puddled with bituminous coal from charcoal pig.

From the uncertainty of the amount of each kind used in the mixture, and a reputation of want of uniformity, it was not considered worth the price charged as compared with the iron of the third experiment.

THIRD EXPERIMENT.—*Three pieces from same sheet.*

| Tensions per Square Inch. | First piece. | | Second piece. | | Third piece. | |
|---|---|---|---|---|---|---|
| | Elongations. | | Elongations. | | Elongations. | |
| | While under tension. | After tension was removed. | While under tension. | After tension was removed. | While under tension. | After tension was removed. |
| 5,000 lbs. | ·00014 | zero. | ·00028 | ·00008 | ·00020 | zero. |
| 10,000 | ·00032 | " | ·00051 | ·00012 | ·00038 | ·00001 |
| 15,000 | ·00053 | " | ·00071 | ·00015 | ·00065 | ·00003 |
| 20,000 | ·00079 | " | ·00113 | ·00027 | ·00086 | ·00006 |
| 25,000 | ·00113 | ·00008 | ·00178 | ·00082 | ·00116 | ·00012 |
| 30,000 | ·00178 | ·00056 | ·00974 | ·00836 | ·00153 | ·00030 |
| 35,000 | ·01698 | ·01542 | ·02954 | ·02869 | ·00237 | ·00105 |
| 40,000 | ·04650 | ·04650 | broke at 38,000 lbs. pr in. | | ·01184 | ·00997 |
| 40,450 | broke. | | | | broke at 44,700 lbs. pr in. | |

NOTE.—A fourth piece from this iron bore 45,100 lbs. per inch.

The iron tested in this experiment was from "charcoal pig," puddled with bituminous coal and worked twice. Finding it possessed a high degree of elasticity, we adopted it for the bridge-work wherever the plates required no change of form.

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*Observations on the Niagara Bridge.** By PETER W. BARLOW, Esq., C.E., F.R.S., F.G.S., &c., &c.

(Continued from page 93.)

*Concluding Observations and Deductions.*

The preceding investigation leads to the inevitable conclusion, viz: that the Niagara Bridge, notwithstanding the defects which have been pointed out, is the safest and most durable railway bridge of large span which has been constructed. First, because it is less liable to deterioration; and, secondly, because the greatest strain to which it can be subjected is a less proportion of the ultimate strength of the supporting material.†

This stability is accomplished in a span of 820 feet by 400 tons of iron, and 600 tons of timber trussing and platform. Had wrought iron been used for trussing, from its superior rigidity the total weight of

* From the London Engineer, No. 253.

† The Fribourg Bridge, as appears from Weale's work on Bridges, has only one-quarter of the section and weight of cable in 870 feet span without any adequate means of preventing undulation, and has stood for 30 years. The durability of the Fribourg Bridge may therefore be doubtful, but it proves beyond question the stability of the Niagara Bridge.

material would not have exceeded 800 tons, the deflection of the wave reduced to 2 ins., and the strain on the cables to one-eighth of their ultimate strength.

It is clear, therefore, that 820 ft. is not the limit of the opening that can be crossed by this principle; it will readily be seen that spans as high as 3000 or 5000 ft. can be carried out for railways, without exceeding the safe limit of strain on the wire cables, and at a cost which would render remunerative connexions and communications which are now considered impracticable.

Navigable rivers may thus be crossed which at present depend for their communication upon ferries; as an instance of which, Liverpool and Birkenhead, and New York and Brooklyn, may be mentioned; and even in London, the sum expended on the Thames Tunnel would have made a useful public communication by this system; and the difficult question of over-crowded streets may be solved, as explained in my recent paper to the British Association, by viaducts of large span, which would interfere very little with the property on the surface.

The dimensions of a bridge to connect Liverpool and Birkenhead will be as follows:

| | |
|---|---|
| Span, | 3,000 feet. |
| Deflection, | 300 " |
| Height of piers, | 450 " |
| Section of cables, | 1,000 inches. |
| Weight of cables between the piers, | 5,085 tons. |
| Weight of suspension rod, | 300 " |
| Weight of platform and girders, | 2,000 " |
| Breaking weight of cable, | 48,000 " |
| Strain at the point of suspension by weight of the bridge, | 11,077 " |
| With a load of 1000 tons, | 12,577 " |
| Weight of wrought iron in towers, | 6,000 " |
| Estimated cost,* | £1,000,000 |

The proposal to build a bridge of these dimensions may be somewhat startling, but let it not be condemned without a fair consideration. It must be remembered that the views here advanced are consistent with the opinions expressed by Telford; and such a proposition as is now submitted would have been received with less scepticism in the year 1814, when he projected the Runcorn Bridge, than it is at the present time, simply because the public have been taught (I believe erroneously) that girders and tubes are the correct principle of bridge construction.

The reasons why any structure is impracticable may be thus classified:—First, that they will not possess sufficient strength and durability when constructed; and, secondly, that it is impracticable to construct them.

The first question, of the strength and durability, is dependent upon the tensile resistance of the material employed. The wire used in the Niagara Bridge was tested by being strained over an opening of 400 feet, until the deflection was reduced to 9 ins.; this is equivalent to straining the same wire over a space of four miles, until the deflection is similar to that ratio proposed for the Liverpool Bridge.

* With piers in the river, a bridge of less cost could be constructed.

If the wire will support its own weight over an opening of four miles, it will evidently have a great excess of strength in three-quarters of a mile; in fact, it will be seen that, in the space proposed, the cables will support four times their own weight plus the greatest load on the bridge; and it would be made a condition of the contract that such strength of the cable should be tested *in situ* (by diminishing the deflection) to three times the strain to which it would be subjected. It will be found that the greatest strain on the metal of the towers, suspension rods, and stiffening girder will be $2\frac{1}{2}$ tons per inch, or $\frac{1}{8}$th of the ultimate strength. If these calculations (which may be checked by any person with a moderate mechanical knowledge) are correct, there can be no doubt of the direct strength of the bridge.

It may be supposed that a bridge of such large dimensions will oscillate with the wind, but it does not appear that oscillation (if by oscillation is meant swinging like a pendulum) is a complaint to which suspension bridges are liable; and if it was, this bridge, from having so much greater weight in proportion to the surface exposed to the wind, would be less liable to this evil, even if constructed with a timber platform in the ordinary way.

It is not generally known that several suspension aqueducts have been constructed with success in America, which, if liable to oscillation, could not long be maintained in condition.

The motion that is observed derives its origin from the undulations of the platform, produced by the agitation, unequal pressure, and change of the direction of the air in a hurricane, and it may be compared to the effect of the platform resting on the surface of water agitated by waves. If the platform has no longitudinal strength, it will undulate in every direction, and necessarily put the chains in a state of vibration, which may be mistaken for oscillation; but I have never detected that oscillation or swinging has occurred in a gale of wind, nor can I see how it is likely to occur. If the wind blew alternately in opposite directions at intervals corresponding with the time of vibration due to the suspension bridge, it would undoubtedly produce serious oscillation; but it does not act in this way. It is variable in some degree in force and direction, but still the general current over a large space will be in one direction, disposing the suspension chains to deviate to some extent from the perpendicular, but not to oscillate.

The observations of General Pasley and Mr. Provis confirm this view; and it is further confirmed by the fact, that no oscillation has been observed in the Menai Bridge (the chains of which being four in depth present a great resistance to the wind), since the longitudinal stiffening, small as it is, has been given to the platform. I will add nothing further to meet an objection that may not be raised, but if it is raised, there is no difficulty in showing that, if a bridge weighing 7500 tons is liable to be influenced by the wind, such a bridge as the Fribourg, with a timber platform, which weighs under 400 tons, in a span of 870 feet, would have been destroyed long before the year 1860.

There does not seem to me any other doubt or difficulty that can be

suggested with reference to strength and durability, and I will now consider the second question, whether there is any impracticability in constructing such a bridge.

The first step is to prepare foundations on each side of the river to carry 30,000 tons, a weight which has been much exceeded in masonry, and cannot be a difficulty.

The second step is to construct wrought iron towers 450 feet high. Masonry and brickwork having been carried nearly that height, it never can be argued that there is a difficulty in a tower of wrought iron 450 feet, with a section of metal allowing only 2½ tons per inch compressure. If it was necessary, and the capital to execute the work, there is no difficulty in building an iron tower 4500 feet high.

We come to the fixing of the cables, which would be a question of some difficulty if chains were employed, but with wire cables the process is perfectly simple, and there is little more difficulty in 3000 ft. span than in 800—except that more powerful machinery is required; and the same may be said of the anchorage, which is a mere question of providing weight in proportion to the strain to be contended with.

The necessity of constructing the platform at such an elevation as to prevent the largest class of ships to pass under (for which 150 feet, or 50 ft. more than the Menai Bridge, has been allowed) is, no doubt, a great drawback to the usefulness of the proposed structure; but much less so than would appear at first sight. One-sixth of the steam power now used at a single ferry would raise all passengers with ease, and comfort, and safety, to the level of the bridge, and the inconvenience would be small compared with that of the uncertainty from gales, fogs, as well as danger of collision, which must always exist in a ferry situated as at Liverpool.

There is little doubt, in spite of the disadvantage, that the work would be of great public utility, and highly remunerative, as it would form a communication not only for passengers, but for road carriage, and by a street tramway would connect the railways on each side of the river.

I have only to add, (should it appear that preconceived notions are not so deeply rooted, that there is a hope of the subject being fairly considered,) that I am prepared, at my own cost, to make experiment on such a scale as will determine, not only that the direct strength is more certain than any previous structure, as every cable will be tested *in situ* to three times its strength, and nothing left for calculation: that the use of wire in the cables and wrought iron in the towers enables the work to be erected with facility and certainty, and moreover that the weight of the structure is so great in proportion to the moving load or force of the wind, the platform being of iron with a stiffening girder, that it is equally certain that the undulation observed in light suspension bridges will be avoided.

The span of the suspension bridge to connect New York and Brooklyn would not require to exceed 2000 ft. Having, therefore, investigated a larger span, it is not necessary to refer to the practicability of a bridge of less dimensions.

The utility of the suspension system girder to relieve the pressure of street traffic in London, will readily be comprehended. There are only three modes of curing an evil (which is becoming beyond endurance, if the business of the City is to be concentrated in the present small area). 1st, To widen the streets and build higher houses; 2d, To make roads or railways under the surface; and, 3d, To make suspension girders, of large span, over the surface. A fourth has been suggested, being street railways.

During my tour in the United States I traveled over between 40 and 50 miles of these railways in New York, Boston, St. Louis, and Cincinnati, and am of opinion that great public benefit will be derived from their introduction in England. A smooth iron road being substituted for paving-stones, the cars are less liable to concussions, and may be constructed much larger without greater weight of material, with height to stand upright, and space to walk with facility from end to end, when the seats are occupied. There results in consequence a degree of smoothness and comfort in traveling, which it is difficult to be understood by those who have only experienced a London omnibus. Cabs are unknown even in New York: if this system was carried out in the approaches to London very great benefit would be derived.

Still the pressure in the City, where the traffic is concentrated and the street narrow, would remain the same, and here the best way of dealing with the difficulty is, in my opinion, to carry the traffic on an upper level by suspension girder viaduct. Two lines of communication, one from east to west, and the other from north to south, would go far towards effecting the object, one commencing at the junction of the Tottenham Court road and Oxford street, passing at the back of the Bank to Whitechapel, and the other commencing at the Elephant and Castle, where the Kent, Newington, and Walworth roads unite, to a point near the Shoreditch station of the Eastern Counties Railway. The cost of a wire suspension girder viaduct with a span of 1000 feet would not exceed for a double line of street omnibus traffic (in connexion with the expected street railways, which will converge at the above described terminal point) £150,000 per mile, to meet fully the requirements of the Board of Trade.

The only land required will be for the wrought iron towers, as a wire bridge may be erected without the least interference with the intermediate property. Allowing £100,000 per acre (the average cost of the terminus of the South Eastern Railway) for the land required, or £50,000 per mile, the whole scheme may be carried out for a little above one million.

Two other applications: wire suspension bridges still occur to me, where bridges have been long projected and abandoned from their cost and interference with property, as hitherto proposed, viz: to connect Holborn and Newgate street by a level bridge, and thus avoid Holborn hill. A wire suspension bridge with towers of wrought iron, constructed like a vertical lattice beam, would offer little obstruction to the light, and would not exceed in cost the sum of £75,000.

The second is a bridge to cross the Mersey at Runcorn, where Telford

projected a chain suspension bridge in the year 1814, having a centre span of 1000 feet, with two side spans of 500 feet.

The construction of a chain bridge of these dimensions at that period was as much at variance with previous notions, and presented as much apparent difficulty as a wire bridge now presents of 3000 feet span, from the superiority of wires over chains, which is so manifest not only from its greater tenacity, but from the facility of erection, that large chain bridges will probably never again be executed.

The cost of a bridge at Runcorn, either for road or railway, with a section of metal such that the strain produced by the greatest weight will not exceed one-fifth of the ultimate strength of every part of the bridge, will not exceed £100,000, and responsible contractors will be found to execute the work for that sum, and probably much less.

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APPENDIX.

*Cornwall Railway—Saltash Bridge.*

Extract from Col. Yolland's Report, dated 25th April, 1859, previous to the opening of the line for traffic.

"I have been favored by Mr. Brereton, who has been acting as chief engineer in Mr. Brunel's absence, with certain particulars, that show the nature and strength of the structure, which are important and may be interesting.

"By the specification under which they were constructed, it is stipulated that the strain per square inch of section, with a load of $1\frac{1}{4}$ tons per foot lineal, should not exceed 4 tons; and with a load of $2\frac{3}{4}$ tons per foot lineal, it was not to exceed 5·5 tons per square inch.

"The west or first tube was accordingly severely tested by the engineers before it was floated to its proper position between the piers, preparatory to its being lifted to the required height by hydraulic pressure. The results were as follow:

"When the tube had to carry itself, and its portion of the bridge being, with the floor, about 1100 tons, the deflection observed at the centre was under $2\frac{1}{4}$ ins. on the east side, and $2\frac{1}{2}$ ins. on the west side, with a load of $1\frac{1}{4}$ tons per foot lineal uniformly laid on the roadway; the deflections were respectively 5·1 ins. east, and 5·25 ins. west, with the load increased to $2\frac{3}{4}$ tons per foot lineal, or 1200 tons; the deflections were $7\frac{1}{2}$ ins. east side, and $7\frac{3}{4}$ ins. west side; but it was noted that during the last two experiments the supports on which the tube rested had sunk about half an inch, which quantity must therefore be deducted from the preceding deflections observed with the load on. After the load of $2\frac{3}{4}$ tons per foot had been taken off, a permanent set of 1·2 ins. on the east side and 1·25 ins. on the west side was observed, beyond that resulting from its own weight, and caused by the heavy weights that had been applied on the roadway.

"On the 20th instant, the day being exceedingly favorable, with a spirit-level placed under the roadway, and resting on the iron stays at the central pier, I observed the deflections at these large openings produced by a load made up of two heavy engines near the centre, and

a number of trucks having their springs packed up, loaded with ballast, iron, &c., making up an aggregate weight of 384 tons, or as large a weight as can possibly be brought on the viaduct, unless the train is made up of a larger number of locomotive engines. The staffs observed were placed at the centres of each opening, and midway between the rails, and thus the deflections observed were the sum of all the deflections, including that of the cross girders carrying the roadway.

"With the above load, the east tube, &c. (not previously tested), deflected 1·14 ins. With the above load, the west tube (test already referred to) 1·20 ins.; and when the weight was taken off there was not the least indication of a permanent set. I then tried to register the deflection caused by passing the whole of this load over the bridge at a speed estimated at 30 miles an hour; but the spirit-level did not remain sufficiently steady to allow of the staff being read, but vibrated, as might be expected, as the train passed. I regard these results as highly satisfactory, and, so far as my knowledge goes, I believe them to be greatly superior to anything of the kind that has been attained elsewhere, and accomplished at less expenditure of money and materials.

"With a load of 1 ton per foot run, and not deducting for any portion of the ends of the tubes immediately resting on the piers, I estimate the amount of the strain on the trussed tubes at about 4·2 tons per square inch of section, and allowing 170 tons as the amount of this superincumbent weight not in any way trying the tube, the strain would be reduced to about 3·8 tons per square inch.

"The strain per square inch of section for the girders over the land openings is also in all cases less than 4 tons."

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## MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

### *Particulars of the Paddle-wheel Steamer Ly-ee-moon.*

Hull built by the Thames Shipping Co., Glasgow, from the designs of a Mr. Ash. Superintendent of construction, Captain Hill. Engines were originally designed by Mr. Taylor, with Messrs. C. J. Mare & Co., during the existence of that firm at the Thames Iron Works, Blackwall. At the period of their failure, they were sold to the owners of this steamer and placed by them into the hands of Messrs. Seaward & Co., of the Canal Iron Works, where they were completed under the direction of Mr. Brunel of that firm. They were set to work under the inspection of Mr. Robert Galloway, to whom the greatest credit is justly due for the success which has been achieved. Boilers by Messrs. Mitchell & Co., Deptford, from Mr. Galloway's designs. Owners, Messrs. Dent, Palmer & Co., Hong Kong, China. Intended service, Hong Kong to Shanghae.

HULL.—Length at water line, 270 ft. 6 ins. Breadth of beam (molded), 27 ft. 3 ins. Depth of hold, 15 ft. 3 ins. Mean draft of water, 12 ft. Frames, of wrought iron plates. Tonnage, 1000 tons. Actual displacement, 1317·7 tons. Displacement per inch, between light and load lines, 12·74 tons. Area of mid-ship section, 282·6 sq. ft. Masts, three, of iron, intended to have been made available for the purpose of ventilating the ship, but are only partially successful.

ENGINES.—Two.—Oscillating. Diameter of cylinders, 70 ins. Length of stroke of piston, 5 ft. 6 ins.

BOILERS.—Four.—Tubular. They are intended to work at a pressure of 25 lbs. per sq. in., and are fitted with Beardmore's admirable super-heating apparatus. These boilers are capable of generating more than sufficient steam under every contingency.

PADDLE WHEELS.—Diameter, 22 ft. The reefing floats are 10 ft. in length by 4 ft. 2 ins. in depth, giving 17 ft. 6 ins. diameter for the effective centres of floats, or 8 ft. 9 ins. from centres of wheel to centres of floats. They were constructed by Messrs. Seaward & Co., and are of great strength.

REMARKS.—This vessel is intended, as stated above, for the China Seas, and is to be engaged in a trade in which the highest attainable speed, combined with economy of fuel, is rather the desideratum than cargo-carrying capacity. Her engine room is supplied with every modern contrivance for registering all manner of interesting facts in connexion with the performance of the engines, and telegraphs, clocks, counters, salinometers, &c., &c., are also there out of number. Silver's governor is fitted with the engine, and is said to work excellently. Messrs. James Taylor & Co.'s superior steam winches, with pumps combined, are to be seen on board in several places.

Coal being exorbitantly high in China, everything that assisted to reduce the consumption which these powerful engines will require, has been introduced in connexion with the boilers, and among them is the admirable invention of Mr. Mitchell, for removing the scale and other deposits that collect upon the interior surfaces of all marine boilers.

The speed attained by this steamer, during her first trial trip, was 16 knots per hour in still water, and during her voyage to the ports of her intended service, a few months since, she joined the U. S. Steam Frigate *Niagara*, and in a run from Puerto Grande to Hong Kong beat her sadly.

The cause of the erection of the *Ly-ee-moon*, and the aim to produce a vessel that could not be easily rivalled in speed, are summed up in the following:

The house of Messrs. Dent, Palmer & Co., the owners of this vessel, is one, if not the most extensive China house in Hong Kong. Their trade is in opium, although exchange, insurance, and silks are ostensibly their business. This firm have owned for years past the *Yang-tsze*, an American steamer 204 feet long, erected, as is well known, by Thomas Collyer, City of New York, and the machinery by the Morgan Iron Works. She plies between the same ports the *Ly-ee-moon* is destined for, carrying nothing but silks, opium, treasure, a few passengers, and the news,—principally, and almost entirely the latter. Captain Dearborn, who commands her, is an American, and receives all the perquisites for passengers, &c., for simply carrying the news in

advance of the regular mail, which he has never failed to do, from twelve to twenty-four hours.

By this means of obtaining the news brought to Shanghae by the Oriental steamships from India and the entire Eastern World, Messrs. Dent, Palmer & Co. are enabled to realize many thousands of dollars every mail, which is regularly twice a month.

The *Yang-tsze* would have continued to do all this business of carrying the news, &c., one steamer being sufficient, had not Messrs. Jardine & Co. (a rival house to Messrs. Dent, Palmer & Co.) constructed a steamer to beat the *Yang-tsze*, to be employed for the same purpose. To beat Messrs. Jardine & Co.'s vessel, the *Ly-ee-moon* was erected, with the view of getting the highest speed ever yet obtained from a sea-going vessel, and in this respect it is highly probable that the construction of it has admirably succeeded.

Before dropping this subject, a word or two more in relation to the steamer *Yang-tsze* may not be out of place. It is with much gratification we have learned that during her three years service in the China Seas, she has sometimes run right into the teeth of monsoons and typhoons, but always coming out perfectly safe and sound, and never has failed in a solitary instance to anticipate the mail. She has never broken down nor had one dollar's worth of repairing done to her whilst she has been running. Messrs. Dent, Palmer & Co. say that when they are done with her, they intend placing her in a glass case for exhibition. These facts reflect the highest credit upon its builders, and is another triumph for American ingenuity and American skill.

E. B.

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*Decision of the Hon. J. Dunlop, Chief Judge of the Circuit Court, District of Columbia, reversing the Decision of the Commissioner of Patents, in the matter of the Application of B. C. Smith for Letters Patent for an Improvement in Iron Pavements.* H. Howson, Counsel for B. C. Smith.

This is an appeal to me from the decision of the Commissioner, refusing a Patent to B. C. Smith for Improvements in Iron Pavements. Mr. Smith does *not* claim "fastening the plates or blocks of iron pavements by mortises and tenons or dowels, or their equivalents;" but his claim is in fact limited to a mode of laying such blocks of iron pavements as follows, to wit: An iron pavement composed of a series of plates laid a given distance apart from each other, and having projections and recesses so proportioned to that distance that the plates, when undisturbed, may form an unyielding pavement, and that one of the plates may be readily removed after a slight lateral movement of the adjacent plates, as herein set forth.

The question presented on this appeal lies within a very narrow compass. Mr. Smith claims to have invented a mode of laying pavements of iron, by which, without disturbing the body of the pavement, particular plates may be taken up and replaced at small cost, to lay down and repair in cities and towns, underground sewers, water and gas pipes.

Heretofore the iron plates, as shown in the references given by the Office, have been laid iron to iron, fastened together by tenons and mortises, so as to fit close, and therefore costly, and difficult to get up without fracture when the purposes above referred to called for their removal.

Smith's mode is to lay the plates about an eighth of an inch apart, and to proportion the mortises and tenons to that distance, filling up the interstices with sand, gravel, or earth, making, when so filled up, an equally solid and compact pavement. When a plate or plates are desired to be removed, the sand or earth in the interstices of the adjacent plates is picked out, which gives room by lateral pressure to take up the plates desired to be removed, without fracture of the plate or tenons, so as to get at the ground below, for laying or repairing sewers, water or gas pipes.

It is not denied by the Office that this contrivance is useful. Smith, it seems, offered to prove it, which was not insisted on, and its utility is apparent on inspection of the papers, models, and drawings. The Office refused to patent it, and the argument in substance of the Board of Appeals is, That the thing was obvious and within the reach of ordinary mechanical skill, and further, the elements were all old and well known.

This argument is answered by the fact that, though iron pavements have been introduced and patented as early as the year 1815, no such device, though useful, has heretofore been contrived by any mechanic who has laid such pavements.

That can hardly be said to be obvious which has taken so long a time to find out.

I agree, it is sometimes difficult to determine where ordinary mechanical skill ends and invention begins.

The best practical principle to guide the Office is that laid down by the Courts of Justice, and which must he regarded as settled Patent law:—That where the combination of known elements produces new and useful results to the public not before attained, then the person who discovers and applies the combination is the inventor within the true intent and meaning of the Patent law. I refer to Prouty & Mears *vs.* Draper, Ruggles, et al., 16 Peters, 336; Godson & Burke's Law of Patents and Copyrights, 63; Many *vs.* Geo. W. Lizer et al., D. C. Mass., in Jan. T., 1849, referred to in Commissioner Holt's decision in Phelan's case; Curtis on Patents, Sec. 24, 73, 94; Ryan *vs.* Goodwin, 3 Sumner's Report, 514, 518; my own decision in the case of Alburtus Laroue, 5th March, 1860.

The Commissioner in his answer to the reasons of appeal says: "Now it seems to me clear, that it is not patentable at this day to lay blocks of any material, to be held together by known fastenings at any given distance from each other, for any purpose."

This asserts the doctrine, if I rightly understand the Commissioner, that no combination of known elements of invention applied in a mode not before practised, however new and useful the results produced by

such combination, is patentable. The authorities I have cited are not in harmony with this position.

Again, the Commissioner in the same paper says: "The determined distance at which the plates shall be placed from each other, so that the change in this distance shall permit the removal of one or more, is a mere arbitrary measure adapted to the particular occasion; but to my mind this adoption of a determined distance to isolate a single plate of the series, is not an invention within the meaning of the Patent law, and derives no patentable novelty from its relation to the mode of fastening selected."

But the determined distance is not arbitrary, it is deliberate, and designed by the applicant, Smith, for attaining a useful purpose.

It is not adapted to the particular occasion only, but is meant for all occasions and all times where iron pavements are to be used; and whether it is patentable or not, I think, depends upon the question, whether the results produced are new and useful, and valuable to the public.

As these results are so new, useful, and valuable, I can see no reason why Smith should be denied a patent. He ought not to be so denied because his invention is simple. In the case of Ryan *vs.* Goodwin, Judge Story said: "The combination is apparently very simple. The simplicity of an invention, so far from being an objection to it, may constitute its great excellence and value. Indeed, to produce a great result by very simple means before unknown or thought of, is not unfrequently the peculiar characteristic of the very highest class of minds."

I sustain the Appellant's reasons of appeal, and do, this 21st December, 1860, reverse the decision of the Hon. the Commissioner of Patents of the date the 30th August, 1860. And I do further, this 21st of December, 1860, adjudge that a Patent be issued to Barzillai C. Smith for the Improvement in Iron Pavements, as claimed by him.

I return herewith to the Office all the papers, models, and drawings, with this my Opinion and Judgment, this 21st December, 1860.

JAS. DUNLOP, *Ch. Judge.*

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*On the Cementation of Iron.* By M. H. CARON, Captain of Artillery.

The processes in use in the arts for the cementation of iron, vary as to the nature of the cement, but all agree in the mode of operating: the piece to be cemented is put into a sheet iron box and surrounded by charcoal dust or soot, or charred leather or horn. Each mode is praised by those who employ it, but the explanation of the fact itself has hitherto remained unknown. While trying to explain the phenomenon, it occurred to me that the combination of the iron and carbon could only take place by means of a gaseous carburet, which might penetrate into the pores of the iron dilated by the heat, and there deposit its carbon. Now it appeared to me, that from the very nature of the cements, this compound must be a cyanide. In order to determine this, I made the following experiments:

The apparatus which I used consisted of a porcelain tube filled with charcoal in pieces of about 1 centimetre cube (0·064 cub. in.); along the axis of the tube was placed a square bar of iron, which was thus entirely surrounded by charcoal. This tube was placed in a reverberatory furnace, and heated with coke. When the apparatus was thus arranged, I passed through the tube heated to redness, successively, hydrogen, carbonic oxide, nitrogen, air and pure carburetted hydrogen. In no case after two hours of heating did I obtain any cementation: sometimes, in a few places, the surface of the iron was a little harder; but in every case, the superficial cementation could be attributed to the impurities of the charcoal or the gas.

When dry ammonia was passed through the tube, the result was different: the cementation was then rapid and excellent. After a two hours heat, the bar withdrawn from the tube, immediately tempered, then hammered to close the grain, then re-tempered, showed in its fracture a cementation of 2 millim. depth (0·08 in.), perfectly regular, and with a magnificent grain. To what cause was the cementation to be attributed? Evidently to the action of the ammonia on the charcoal: these two bodies at that temperature must have formed a gaseous cyanide of ammonium, which gave up its carbon to the iron and gave rise to the steel.

But this was only an hypothesis; I desired to establish directly the action of the cyanide of ammonium. For this purpose, I removed the charcoal in the porcelain tube, leaving the iron bar in the axis and supported at its ends. I prepared the cyanide of ammonium in a retort, and passed it through the porcelain tube while red hot. After heating for two hours, the bar was withdrawn and treated as before; it was perfectly cemented, and the end at which the gas entered was more so than the other. I therefore thought that I might conclude that in these experiments, the cementation was caused by the cyanide of ammonium.

It was not probable that the cyanide of ammonium should alone have this property; it was more likely that the other alkaline cyanides would act in the same way. The temper by the prussiate well known in the arts was a proof of this; unfortunately in this case, the cementation, which is only superficial, cannot be compared with the other.

I had therefore to employ other means to succeed in establishing the cementation by the alkaline cyanides.

My apparatus was arranged as before; the charcoal was soaked in a weak solution of carbonate of potassa; and I passed through the tube heated to redness, a very slow current of dry air. It is known that under these circumstances cyanide of potassium is formed, which is sensibly volatile at a red-heat. It was on the formation of this substance that I calculated to cement the iron. In fact, after two hours heating the bar showed a magnificent cementation of a depth of 2 millimetres.

Soda, baryta, and strontia cement nearly in the same way under the influence of a current of air. As to lime, it produced, as I expected, no cementation.

All the recipes in use for the cementation of iron may be explained by the formation of cyanides. The charcoal used always contains potassa or soda; the animal matters which are added, bring with the alkali the nitrogen which is to transform it into a cyanide.

In fine, it seems to me that these experiments show irrefutably that in order to obtain a rapid and deep cementation, the formation of the alkaline cyanides should be promoted in the charcoal surrounding the iron. The application of this truth will be very easy in the arts. We may perhaps be able, by this means, to diminish very much the time necessary for the process, and thus keep a much greater tenacity in the mass of the metal which the cementation has not reached.

*Annales de Chimie et de Physique*, October, 1860.

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*On the Melting-points of some of the Elements.* By WILLIAM CROSSLEY, Assay Master, Ormesby Ironworks, Middlesborough.

From the Lond. Chemical News, No. 35.

It is remarkable that in almost all the series or groups of the elements mentioned by Mr. Coleman there appears to exist a peculiar relation between the atomic weight and the melting point, which to a certain extent confirms his opinion that the equivalent number of an element expresses a certain amount of force, modified by its atomic volume. As an illustration we will take the group zinc, palladium, platinum.

| | At. Weight. | At. Vol. | Melting Point. |
|---|---|---|---|
| Zinc, | 33 | 57 | 773° F. |
| Palladium, | 53 | 57 | Highest heat of wind furnace. |
| Platinum, | 98 | 57 | Oxyhydrogen blowpipe. |

Here we have a group of elements having a like atomic volume with an increasing atomic weight, not only decreasing in active chemical attraction, but decreasing in fusibility as the weight of the atom increase. Does the atomic weight here represent a force? We think so, because it appears general. Let us pass on to some other groups.

| | At. Weight. | At. Vol. | Melting Point. |
|---|---|---|---|
| Sulphur (crystallized), | 16 | 101 | 239° F. |
| Selenium, | 40 | 101 | 420° |
| Lead, | 103·7 | 114 | 617° |
| Silver, | 108 | 128 | 1873° |
| Gold, | 197 | 128 | 2016° |
| Chlorine (liquid), | 35·5 | 320 | Gaseous at com. temp. |
| Bromine, | 80 | 320 | Liquid do. |
| Iodine, | 127 | 320 | Solid do. |
| Aluminium, | 14 | 66 | Red heat. |
| Chromium, | 27 | 66 | Agglomerate but not fuse at the highest heat of the wind furnace. |
| Molybdenum, | 46 | 66 | |
| Tungsten, | 95 | 66 | |

Here we have four groups, in each of which the elements having the least atomic weight offer the least resistance, not only to the action of other elements, but also of heat. In so many groups, taken,

as it were, at random, it cannot all be accident. There are, however, exceptions: we find them in the groups

| | At. Weight. | At. Vol. | Melting Point. |
|---|---|---|---|
| Manganese, | 27·6 | 44 | Highest *heat* of wind furnace. |
| Iron, . | 28 | 44 | " " |
| Cobalt, . | 29 | 44 | " " |
| Nickel, . | 29 | 44 | " " |
| Copper, . | 32 | 44 | 1996° F. |
| Phosphorus, | 33 | 211 | 111° |
| Antimony, . | 129 | 224 | Red heat. |
| Bismuth, . | 213 | 270 | 507° |

Manganese and iron, and perhaps cobalt and nickel, follow this law, but copper varies very much; for this we can see no reason. Phosphorus and antimony follow the law, but bismuth comes between. What can influence it? Look at its atomic volume; it differs 59 from that of phosphorus. We cannot, therefore, be much surprised at its having a different melting point.

These facts support Mr. Coleman's views. The subject is interesting and well worth discussing.

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Translated for the Journal of the Franklin Institute.

## *Mathematical Theory of the Dynamical Effects of Heat given to a Permanent Gas.** By M. J. Bourget, Professor of Mathematics in the Faculty of Sciences at Clermont.

Up to the present time, the theory of the motive power of heat has been treated, by assuming *á priori* the following propositions:—

*It is absurd to admit the possibility of creating either moving force or heat.*

*Heat cannot be made to pass from a colder to a warmer body.*

*In all cases where mechanical work is produced by heat, there is a consumption of a quantity of heat proportional to the work done; reciprocally, this quantity of heat may be represented by a quantity of mechanical work equal to that before spoken of.*

I am about to undertake the same subject in a different way, confining myself to the case in which a permanent gas is the vehicle of the heat.

It seemed to me that if the principles above mentioned are true; if it be true that heat and mechanical work may be regarded as homo-

* Works to be consulted on the question of the Mechanical Equivalent of Heat:—

Joule.— Memoir on the heating effects of magneto-electric currents; and on the mechanical equivalent of heat. *Annales de Chimie et de Physique*, Tome XXXIV.

Joule.— On the mechanical equivalent of heat.

Mr. W. Thomson.— Examination of Carnot's theory of the motive force of heat.

Clausius.— On the motive force of heat. *Annals de Chimie et de Physique*, Tome XXXV.

Quintus Icilius.— Memoir on the numerical values of the constants which enter into the expression for the heat disengaged by currents.— *Annales de Chimie et de Physique*, Tome LI.

Clausius.— On the motive force of heat, and on the laws resulting from it.— *Bibliotheque Universelle de Geneve*, Tome XXXVI.

Mr. W. Thomson.— Two memoirs on the dynamic theory of heat.— *Liouville's Mathematical Journal*, Tome XVII.

Reech.— General Theory of the dynamical effects of heat.— *Journal des Mathematics*, Tome XVIII.

See also the memoir entitled "A new system of Air Engine, deduced from a comparison of the systems of MM. Ericsson and Lemoine," by M. Reech.

geneous, and capable of being transferred the one into the other by equivalents; if, in one word, perpetual motion is impossible for hot-air engines as for others; this ought to be demonstrated, starting from known physical laws, and the formulæ deduced from these laws. I have not been deceived in my hope; and the mechanical equivalent of heat will here be seen deduced from the laws of Mariotte, Gay-Lussac, Dulong, and Regnault.

In another essay, in collaboration with M. Burdin, I studied the air machines, using the formulæ of Poisson which connect the pressures, densities, and temperatures of a given mass of gas, compressed or dilated, without being directly heated or cooled. Many of the consequences here noticed flowed from these formulæ. But it was not without hesitation that I assumed the formulæ of this illustrious mathematician as my base; the reasoning by which they were reached does not appear to me free from objection.

I have happily succeeded in removing this difficulty, and I have found a new and very simple demonstration of the same formulæ, which clearly shows the only hypothesis necessary to arrive at them.

Although confined to permanent gases, my analysis appears to me to give a certain degree of probability to that fruitful and seductive conception, the homogeneousness of the natural agents. Is it not, in fact, a thing well worthy of attention, that laws and formulæ found without any pre-occupation with the new principles, implicitly contain them?

SECTION 1.—Definitions and Preliminary Formulæ.

1. *Mathematical Representation of the State of a Gas.*

Three quantities determine completely the state of a permanent gas: its elastic force ($p$); its volume ($v$); and its temperature ($t$). We shall express its pressure in kilogrammes per square metre;* its volume will be referred to the cubic metre, and its temperature measured in centigrade degrees. To fix the ideas, we may, in what follows, suppose the gas enclosed in a cylinder of a square metre cross section, beneath a movable piston without weight, and always loaded with a pressure equal to its own elastic force.

Between these three variables, $p$, $v$, and $t$, there is a relation resulting from the laws of Mariotte and Gay-Lussac combined; for by denoting by $p_0$, $v_0$, and $t_0$ the values of these variables for another state of the gas, we have, $\frac{p\,v}{1+\alpha t} = \frac{p_0\,v_0}{1+\alpha t_0}$; whence, $p\,v = m(1+\alpha t)$ (1)

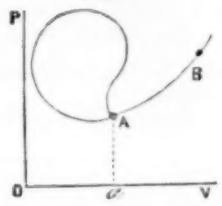
$m$ being a constant, and $\alpha$ the co-efficient of dilatation, which is sensibly constant for all the gases. To determine $m$, make $t_0 = 0°$, call H the normal pressure of 0·76 referred to the square metre, and let us suppose that we are considering one cubic metre of gas at this pressure and temperature; then we shall have $m = \text{H} = 10{,}333$ kil.; whence we obtain, $p\,v = \text{H}\,(1+\alpha t)$. (2)

*The French units have been preserved in this translation. The kilogramme is 2·2047 lbs.; the cubic metre is 35·352 cub. ft., or 1·331 cub. yds. The square metre is 1·196335 sq. yds., or 10·767 sq. ft. The centigrade degree is equal to 1·8 Fahrenheit degrees. The millimetre is 0·039354 ins.; whence, 0·76 mil. = 29·93184 ins. The normal pressure used in England and in this country is 30 inches.

This is the form which we shall use in the subsequent calculations.

According to equation (2), it is sufficient to know the two quantities $p$ and $v$, in order to know the state of a gas. Let us then trace two rectangular axes, and let us take the volumes as the abscissas and the pressures as ordinates. It is evident that any state of the gas will be represented by a point such as A; a series of different states infinitely near each other will form a curve such as A B; if this curve re-enters itself and returns to its point of departure, it will form a *closed circuit.*

Fig. 1.

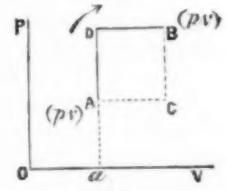



If we assume $$p\,v = \text{H}(1 + \alpha t) = \text{const.} = \theta, \qquad (3)$$ we obtain a hyperbola having for asymptotes the axes of co-ordinates; any point in this curve represents a state of the gas for which the temperature is constant.

2. *Expenditure of Heat in describing a rectangular closed circuit.*

Let A $(p\,v)$ be the initial state of a gas; by lines parallel to the axes, trace the closed circuit, A D B C A; cause the gas to pass through the different states which correspond to this circuit described in the direction of the arrow, and let us seek for the heat expended.

Fig. 2.




1. While the gas is passing from A to D, it is being heated under constant volume; the temperature $t_1$ is given by the formula $p'\,v = \text{H}(1 + \alpha t_1)$, which, combined with $p\,v = \text{H}(1 + \alpha t)$, gives $(p' - p)\,v = \text{H}\,\alpha\,(t_1 - t)$.

The expenditure of heat will be $$q = \text{D}\,c'\,(t' - t),$$ D denoting the weight of a cubic metre of air at 0°, and $c'$ the specific heat under constant volume.

By substitution, this expression becomes $$q = \frac{\text{D}}{\text{H}\,\alpha}\,c'\,v\,(p' - p). \qquad (4)$$

2. While the gas passes from the state D to the state B, it is being heated under constant pressure; the temperature $t'$ is given by the formula $p'\,v' = \text{H}(1 + \alpha t')$, which combined with $p'\,v = \text{H}(1 + \alpha t_1)$, gives $p'(v' - v) = \text{H}\,\alpha(t' - t)$; the expenditure of heat is $q_1 = \text{D}\,c(t' - t)$, $c$ being the specific heat under constant pressure.

This formula becomes by substitution, $$q_1 = \frac{\text{D}}{\text{H}\,\alpha}\,c\,p'\,(v' - v). \qquad (5)$$

3. While the gas passes from the state B to the state C, it is cooled under constant volume; its temperature $t_2$ is given by the formula $p\,v' = \text{H}(1 + \alpha t_2)$, which combined with $p'\,v' = \text{H}(1 + \alpha t')$, gives $(p' - p)v' = \text{H}\,\alpha\,(t' - t_2)$. The heat obtained will be $q' = \text{D}\,c'\,(t' - t_2)$, or

$$q' = \frac{\text{D}}{\text{H}\,\alpha}\,c'\,v'\,(p' - p). \qquad (6)$$

4. Finally, while the gas passes from the state C to its primitive

state A, it cools under constant pressure; its temperature again becomes $t$ given by the formula $p\,v = \text{H}\,(1 + \alpha\,t)$, which combined with $p\,v' = \text{H}\,\alpha\,(1 + \alpha\,t_2)$, gives $p\,(v' - v) = \text{H}\,\alpha\,(t_2 - t)$.

The heat obtained will be $q'_1 = \text{D}\,c\,(t_2 - t)$ or by substitution, $q'_1 = \frac{\text{D}}{\text{H}\,\alpha}\,c\,p\,(v' - v)$. (7)

In fine the expenditure of heat will be

$$\text{Q} = q + q_1 = \frac{\text{D}}{\text{H}\,\alpha}\,[c'\,v\,(p' - p) + c\,p'\,(v' - v)]$$

the heat obtained will be

$$\text{Q}' = q' + q'_1 = \frac{\text{D}}{\text{H}\,\alpha}\,[c'\,v'\,(p' - p) + c\,p\,(v' - v)]$$

The whole expenditure will therefore be

$$\text{Q} - \text{Q}' = \frac{\text{D}}{\text{H}\,\alpha}(c - c')\,(p' - p)\,(v' - v)$$

As this quantity cannot be equal to 0, we reach this remarkable result:

*When a gas leaves any given state, it cannot return to it, after following a rectangular circuit of successive states, without the disappearance of a quantity of heat which is proportional to the surface* $(p' - p)\,(v' - v)$ *of the circuit.*

3. *Remark* 1*st.*—The preceding law proves that the quantity of heat necessary to pass a gas from one state A, to another B, depends not only on these extreme states, but also on the intermediate ones. It is, I believe, the first time that this truth has been shown by deducing it from the admitted laws of the action of heat upon the gases. In fact, I find in a condensation of the work of Clausius, by my friend M. Verdet (*Annales de Chimie et de Physique*, tome xxxv, p. 483), the following passages:—"When a gas passes from the temperature $t_0$ and volume $v_0$, to the temperature $t$ and volume $v$, it is generally admitted that the heat which it gains or loses depends only on the initial and final values of the temperature and volume. This is impossible if there be an equivalence between the mechanical work and the heat."

We see from the above process that it is not necessary to invoke any new principle for the purpose of proving this impossibility.

4. *Remark* 2*d.*—We might have followed the circuit in the opposite direction; there would then have been *gain* instead of *loss* of heat, and the quantity gained would still have been proportional to the area A *c* B D.

5. *Remark* 3*d.*—Our reasoning shows that $a\,c\,c'$ depend neither on the temperature nor on the pressure. M. Regnault has established that $a$ and $c$ are subject to this law. As to $c'$ its determination is more difficult; MM. Gay-Lussac and Welter deduced from their experiments, that the ratio ($\gamma$) of these two specific heats is sensibly independent of the temperature and pressure, in the case of the atmospheric air; and it follows that $c'$ must be nearly invariable also.*

* At the same time, we do not think that much confidence should be given to this result. We shall therefore make no supposition as to $c'$, but shall place ourselves in such limits of temperature and pressure, as to allow $c'$ to be considered constant as well as $a$ and $c$.

6. *Remark 4th.*—If the point B is indefinitely approximated to A, the expenditure of heat approaches zero. In other words, to pass from the state A to another B infinitely near it, the same amount of heat must be expended whether you follow the route A *c* B or A D B. The two expenditures are, omitting an infinitely small quantity of the second order,

$$Q = \frac{D}{H\,a}\,(c'\,v\,d\,p + c\,p\,d\,v).$$

7. *Effective work of the gas in describing the rectangular circuit.* Supposing, as we have done, the gas to be in a cylinder of a square metre of cross-section, and under a piston always equilibriated. It is seen that the effective work along the path A B D is $W = p'\,(v' - v)$.

The resistance through the path B *c* A is $W' = p\,(v' - v)$.

Then the effective work of the gas through the whole of the closed circuit is $W - W' = (p' - p)\,(v' - v)$

and is therefore represented by the area of the rectangle formed by the circuit.

8. *Elementary Demonstration of the Principle of the Equivalent.* If we compare equations (10) and (14) we deduce

$$Q - Q' = \frac{D\,(c - c')}{H\,a}\,(W - W').$$

The co-efficient under the vinculum is constant for the same gas, for the pressures and temperatures used. Let us make then $E = \frac{H\,a}{D\,(c - c')}$

and we shall have $Q - Q' = \frac{1}{E}\,(W - W')$.

Therefore, "*The quantity of heat lost is proportional to the effective work done, and reciprocally; so that to each calory* lost, corresponds an effective work produced equal to* $E^{k\,m.}$.

Therefore without disquieting ourselves to know what heat is, we may at all events say, *that every thing takes place as though heat transformed itself into mechanical force at the rate of* $E^{k\,m.}$ *for each calory lost.*

This number E may be called *the mechanical equivalent of heat;* assuming $H = 10{\cdot}333$ k; $a = 0{\cdot}003665$; $D = 1{\cdot}293187$; $c = 0{\cdot}2377$; $\gamma = \frac{c}{c'} = 1{\cdot}41$ (Masson). We find in round numbers $E = 424$ kilogrammetres.†

9. *Remark 1st.*—This number necessarily presents some uncertainty, since physicists are not all agreed as to the value of $\gamma$. This is the reason that we have only assumed only the whole numbers.

10. *Remark 2d.*—If the closed circuit had been described in the opposite direction, the work would have been resisting in place of effective; nevertheless the formula would not have changed and we should have reached the following conclusion:

* A *calory* is an unit of heat; as for instance the quantity of heat necessary to raise 1 kilogramme of a gas one degree of temperature.

† This, in English measure, is 773 lbs. raised one foot high per degree Fahrenheit.

"*The heat produced is proportional to the resistance of the gas in the proportion of* $E^{k\,m.}$ *for each calory.*"

The first proposition includes both cases, provided we admit once for all, that a negative quantity of heat lost is that quantity of heat gained; and that a negative quantity of work done represents that quantity of resistance.

11. *Remark 3d.*—The demonstration which we have given of the transformation of heat into mechanical work, in this particular case, may be introduced into the elements of Physics; it moreover shows the method to be followed to verify experimentally the truth of all our considerations.

In fact: either *first* there is an equivalent of heat, and in that case the number E is mathematically constant; then for all the gases we shall have

$$\frac{a}{D\,(c - c')} = \text{const.} = \frac{a}{D\,c\left(1 - \frac{1}{\gamma}\right)};$$

and this law is mathematical. Besides, as $a$ is sensibly the same for all we must have

$$D\,(c - c') = D\,c\left(1 - \frac{1}{\gamma}\right) = \text{const.}$$

Therefore: *in different gases, the differences of the two specific heats for the same weights, are inversely as their densities:* or taking the specific heats of equal volumes; *the difference of these specific heats is the same for all the gases.*

Moreover, Dulong proposed this law that equal volumes of different gases require the same quantity of heat to raise them the same number of degrees; this is the law of the specific heat of atoms. Therefore $D\,c$ = constant for a certain number of permanent gases; therefore for all these $\gamma$ = constant.

For the same gas, the absolute invariability of E requires the invariability of $c - c'$, and consequently that of $c'$, since $c$ is nearly invariable; and consequently that of $\gamma$.*

Or else, *secondly*, the equivalent E does not exist in the sense assumed by Clausius, Joule, Seguin, &c. In this case our formula will still remain for small intervals of temperature and pressures; but for every different interval the co-efficient E is different. In this case E = function (*p. t.*), and the preceding conclusions do not stand.

Thus we see that if we should succeed in proving that the ratio $\gamma$ is constant for the same gas, we should have made an important verification of the existence of a mechanical equivalent of heat.

Our calculations show plainly that this hypothesis of the invariability of $\gamma$ necessarily leads to the admission of the transformation of heat into mechanical work. This is the reason that this may be deduced from the formulæ of Poisson, which only assume this invariability.

*All these results were found by Clausius, as consequences of the hypothesis made *a priori* that there was a mechanical equivalent of heat.

For the Journal of the Franklin Institute.

## *Particulars of the Steamer Louisiana.*

Hull and machinery by Harlan, Hollingsworth & Co., Wilmington, Del.

Hull.—Length on deck, 147 ft. Do. at load line, 140 ft. Breadth of beam (molded), 27 ft. Depth of hold, 8 ft. Do. to spar deck, 15 ft. 6 ins. Length of engine and boiler room, 35 ft. Frames—molded, 3 ins.; sided, $\frac{3}{4}$ in.—apart at centres, 16 ins. Sketch of shape, |; depth, 3 ins. 9 strakes of plates from keel to gunwale; thickness of plates, $\frac{3}{8}$ and 5-16 in. Description of cross floors, 8 T, 14 ins. high. Depth of keel, 4. Diameter of rivets, $\frac{3}{4}$ in., double riveted. One independent steam, fire, and bilge pump. Two bulkheads. 8 fore-and-aft keelsons, 14 ins. high × $\frac{3}{4}$ in. thick, T. Draft, forward and aft, 7 feet. Tonnage, 353·45. Area of immersed section at load draft of 7 feet., 160 sq. ft. Displacement at load line, 438 tons. Masts, three.—Rig, schooner.

Engine.—Inverted direct-acting. Diameter of cylinder, 32 inches. Length of stroke, 2 feet 4 ins. Maximum pressure of steam, 30 lbs. Cut-off at half-stroke. Maximum revolutions at above pressure, 84. Weight of engines, 43,334 lbs.

Boiler.—One—Return flued. Length of boiler, 18 feet. Breadth of do., 7 ft. 9 ins. Height do., exclusive of steam chimney, 7 ft. 3 ins. Weight do., with water, 35,760 lbs. Number of furnaces, two. Breadth do., 3 ft. 4 ins. Length of grate bars, 5 ft. Number of flues, above, 16; below, 10. Internal diameter of flues, above, 6½ ins.; below, 2 of 16 ins., 8 of 8½ ins. Length of flues, above, 13 ft. 4 ins.; below, 10 ft. 10 ins. Grate surface, 34 sq. ft. Heating surface, 843 sq. ft. Diameter of smoke pipe, 3 feet. Height do., above grates, 33 feet. Consumption of fuel per hour, 560 lbs.

Propellers.—Diameter of screw, 8 ft. 2 ins. Length do., 4 feet. Pitch do., 15 feet. Number of blades, four.

Date of trial, December, 1860. C. H. H.

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For the Journal of the Franklin Institute.

## *Particulars of the Steamer Han-kow.*

Hull built by Thomas Collyer. Machinery by Morgan Iron Works, New York. Owners, J. M. Forbes & Bros. Intended service, Coast of China.

Hull.—Length on deck, 212 ft. Do. at load line, 210 ft. Breadth of beam (molded), 30 ft. 6 ins. Depth of hold to spar deck, 11 ft. 4 ins. Frames—molded, 14 ins.; sided, 7 ins.—apart at centres, 27 ins.; strapped with diagonal and double laid braces, 3½ × ½ in. Tonnage, 717. One independent steam, fire, and bilge pump. Area of immersed section at load draft of 7 feet, 176 sq. ft. Displacement at load line, 725 tons. Masts, two—schooner rigged.

Engine.—Vertical beam. Diameter of cylinder, 48 inches. Length of stroke, 12 ft. Maximum pressure of steam, 30 lbs. Cut-off at half-stroke.

Boilers.—Two—Return tubular Length of boilers, 20 feet. Breadth do., 11 feet. Height do., exclusive of steam chimney, 9 ft. 6 ins. Number of furnaces, two in each. Breadth do., 4 ft. 9 ins. Length of grate bars, 7 feet. Number of tubes, above, 64;

flues, below, 10 in each. Internal diameter of tubes, above, 5¼ ins.; flues, below, 8 of 12½ and 2 of 15½ ins. Length of tubes, above, 14 ft.; flues, below, 7 ft. 10 ins. Grate surface, 133 sq. ft. Heating surface, 4500 sq. ft. Diameter of smoke pipe, 5 ft. 10 ins. Height do., above grates, 32 ft. Consumption of fuel per hour, 740 lbs.

PADDLE WHEELS.—Diameter over boards, 29 ft. Length of blades, 8 ft. Depth do., 24 ins. Number do., 26.

*Remarks.*—Water-wheel guards fore-and-aft, half width.
Date of trial, January, 1861. C. H. H.

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For the Journal of the Franklin Institute.

## *Particulars of the Steamer Thomas Freeborn.*

Hull built by Laurence & Foulke. Machinery by Allaire Works, New York. Intended service, New York Harbor and Coast.

HULL.—Length on deck, 143 ft. Do. at load line, 140 ft. Breadth of beam (molded), 25 ft. Depth of hold to spar deck, 9 ft. Frames—molded, 14 ins., sided, 5 ins.—apart at centres, 16 ins. One independent steam, fire, and bilge pump. Draft, forward, 5 ft. 6 ins., aft, 6 ft. Tonnage, 305. Area of immersed section at load draft of 6 ft., 127 sq. ft. Displacement at load line, 345 tons.

ENGINE.—Vertical beam. Diameter of cylinder, 40 ins. Length of stroke, 8 feet. Maximum pressure of steam, 30 lbs. Cut-off—one-half. Maximum revolutions at above pressure, 30.

BOILER.—One—Return flued. Length of boiler, 22 ft. Breadth of do., 10 ft. 3 ins. Height do., exclusive of steam chimney, 9 ft. Number of furnaces, two. Breadth do., 4 ft. 5½ ins. Length of grate bars, 7 ft. Grate surface, 62 sq. ft. Number of flues, above, 16; below, 10. Internal diameter of flues, above, 9½ ins.; below, 2 of 19 and 8 of 12 ins. Length of flues, above, 15 ft. 3 ins.; below, 9 ft. Heating surface, 1457 sq. ft. Diameter of smoke pipe, 4 ft. Height do., 47 ft.

PADDLE WHEELS.—Diameter over boards, 20 feet. Length of blades, 7 ft. 6 ins. Depth do., 24 ins. Number do., 14.

Date of trial, January, 1861. C. H. H.

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For the Journal of the Franklin Institute.

## *Particulars of the Steamers Suffolk Co., and King's Co.*

Hull built by Roosvelt & Joyce. Machinery by Allaire Works, New York. Owners, East River Ferry Co.

HULL.—Length on deck, 143 ft. Do. at load line, 143 ft. Breadth of beam (molded), 32 ft. Depth of hold, at ends, 11 ft; at centre, 12 ft. Frames—molded, 14 ins., sided, 6 ins.—apart at centres, 24 ins. One independent steam, fire, and bilge pump. Draft, forward and aft, 6 ft. 3 ins. Tonnage, 500. Area of immersed section at load draft of 6 ft. 3 ins. 175 sq. ft. Displacement at load line, 555 tons.

ENGINE.—Vertical beam. Diameter of cylinders, 34 ins. Length of stroke, 9 feet. Maximum pressure of steam, 25 lbs. Cut-off, Sickel's adjustable.

BOILER.—One—Tubular return. Length of boiler, 21 ft. Breadth do., 10 ft. Height do., exclusive of steam chimney, 10 feet. Number of furnaces, two. Breadth do., 3 ft.

5 ins. Length of grate bars, 6 ft. 6 ins. Number of tubes, above, 134; flues below, 8. Internal diameter of tubes, above, 3 ins.; flues, below, 15 ins. Length of tubes, above, 17 ft.; flues, below, 8 ft. 8 ins. Grate surface, 46 sq. ft. Heating surface, 2400 sq. ft. Diameter of smoke pipe, 3 ft. 4 ins. Height do., 40 ft.

PADDLE WHEELS.—Diameter over boards, 19 ft. Length of blades, 6 ft. 6 ins. Depth do., 24 ins. Number do., 18.

Date of trial, December, 1860. C. H. H.

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Translated for the Journal of the Franklin Institute.

## *Fabrication of Sugar.*

At the meeting of the Academy of Sciences of Paris held 14th January, 1861, M. Dumas presented in the name of M. Emile Rousseau a memoir on a means of purifying vegetable juices, applied to the making of sugar. In consequence of the immense importance of this work, we publish an extensive analysis of it, for which we are indebted to the kindness of the author.

In the juices of the saccharine vegetables, that of the beet being taken for an example, we find always two kinds of organic substances which oppose the extraction of the sugar. The first belongs to the group of albumenoid and caseoid matters. It undergoes all the modifications which reagents exert upon the solutions of albumen and casein. The salts of lime, and lime coagulate it. But this latter, whether by its own proper alkaline action it dissolves a portion of the vegetable substance, and holds it in combination, as M. Frenay has lately shown; or whether it liberates potassa or soda, causes the juices treated by it to remain always alkaline after the action of carbonic acid. These two effects are even found united, and there results from them a subsequent change of the syrups, which is especially felt in the low products of the manufacture of sugar.

The second substance is a matter generally colorless as long as it remains in the cells of the plant; but very greedy for oxygen, coloring rapidly under the action of the air, modified very easily by oxidizing agents, so as to be either transformed into that well known brown substance which appears, when vegetable juices are evaporated, or entirely destroyed. This substance, indeed, when it is deprived of all the albumenoid matter, reduces by heat the salts of silver, the binoxide of mercury, &c. By the action of this last material, the solution even takes the natural tint which the juice possesses after long exposure to air.

These facts being established, the data of the problem of the simplification of the making of sugar may thus be stated: We must find, 1st, a substance, generally but slightly soluble, having the power of coagulating all albumenoid substances, without any injurious action either on the sugar, or on the health; which can easily be withdrawn from the juice in case a certain quantity should remain in solution; and finally

shall be of low price. 2d, Another substance, of an oxidating power, so to speak, limited; which may by its action either destroy the coloring matter or transform it into the brown substance and then absorb it; in short, shall add to this absorbing action the innocuousness and the low price of the former.

Sulphate of lime in whatsoever state it may be, natural or artificial (raw or calcined plaster), is the substance which appears to me to fulfil all the above indications better than any other material which I have studied. It is neutral, a condition which I regard as indispensable: without action on the sugar, but slightly soluble: it unites to the conditions of harmlessness and low price, a most remarkable property of coagulating the albumenoid matters of vegetable juices, of that of the beet in particular. This property is such that it requires but a relatively very small quantity of its solution to produce this effect. The operation of defecation can therefore be performed under these excellent conditions, and with but a small quantity of matter; the head is very firm, collects well, and the juice can be drawn off in a proper state of clearness. The sulphate of lime therefore removes perfectly all coagulable matter, but does not touch the coloring matter, so that after the separation of the head, the juice soon colors deeply.

Animal charcoal is almost without effect immediately after defecation; it removes only the matter which is already oxidized, for after its action, the juice whose coloration is much lessened, soon colors again. We want therefore an oxidizing agent which shall do in a short time that which the air produces at length, or which may so modify this substance as to destroy or absorb it. Among the numerous bodies which I have examined in reference to this point, and which I shall not now enumerate, the hydrated peroxide of iron presents superior advantages in all respects.

Thus, after having removed by the sulphate of lime all the coagulable matters of a saccharine juice, if we agitate it either cold, or heated to a temperature which must never reach ebullition with hydrated peroxide of iron, the filtered liquor passes altogether decolored, and purified from almost all the foreign matters which it contained. Besides this, the peroxide of iron, by that property, which all chemists know it to possess, of absorbing the alkaline and earthy salts, removes the small quantity of sulphate of lime which remained in solution. Thus the juice which after the defecation by the sulphate of lime, reduced the nitrate of silver, &c., causes no change in them after its contact with the peroxide of iron.

This juice when it comes from a plant in the normal condition, is, after this purification, perfectly neutral to test-papers, and may be kept in contact with the air for several days without undergoing the slightest alteration or coloration, which proves that all the matters which could act as ferments have been removed. It boils very well, and does not color even by the action of heat. The syrup when concentrated to the proper point possesses only that slight yellow tint which belongs to the purest syrups. It tastes well, is deprived of the saline and disagreeable taste which we find in all beet-syrups, and

preserves a remarkable fluidity and limpidity. The crystallization takes place easily and the crystals are white.

As a final proof of the good purification of the saccharine juice by this method, if we add to a boiled syrup a proper quantity of water to bring it back to 25° or 30° of the areometer, and in that state mix it with a large excess of alcohol at 90°, no cloudiness or deposit takes place even after several days; it no longer retains a trace of iron.

Henceforth, the making of sugar is reduced to these manipulations only: heating the saccharine juice in a boiler with some thousandth parts of sulphate of lime (natural plaster is the best); all the coagulable matters unite in a firm head; the clear juice separated from this, is then stirred with peroxide of iron. After the separation of the oxide, nothing remains to be done but to evaporate the water; that is to boil down.

The hydrated peroxide of iron must be in the state of a firm paste. A litre (quart) weighs about 1145 grammes (2½ lbs.); it contains from 70 to 80 per cent. of water. The quantity to be employed varies with the juice; it is never more than 8 or 10 per cent of the juice, which amounts to 2 per cent. about of the solid matter, the rest being water. After its action on the syrup it takes a black color, shrinks and separates easily from the liquid. After it has been used, it is only necessary to wash it with warm water, after having left it exposed to the air, in order to give the organic matter which it has absorbed time to be destroyed, so that the deoxidized portion may take again the oxygen which it has lost. It may be used, as is seen, over and over again indefinitely, and requires but little expense for its regeneration. This fortunate property renders the question of the quantity to be employed of but little importance.

I will add in conclusion, that even now, its price is much below that of animal charcoal, for it may be supplied at 5 or 6 f. per 100 kilog. ($8 to $12 per ton), and this price will doubtless be much reduced hereafter.—*Cosmos.*

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For the Journal of the Franklin Institute.

*Strength of Materials:* Deduced from the latest experiments of Barlow, Buchanan, Fairbairn, Hodgkinson, Stephenson, Major Wade, U. S. Ordnance Corps, and others. By Chas. H. Haswell, Civil and Marine Engineer.

## No. 5.

(Continued from page 114.)

*Formulæ to Ascertain the Values and the Dimensions of Bars, Beams, &c., of Various Sections.* (By Thomas Tredgold.)

For a Square, Rectangle, Rectangle, the diagonal being vertical, and Cylinder, they are alike to those already given, substituting in the rectangles, for $b\ d^2$, $s^3$.

For a Grooved, or Double flanched, Open, and Single flanched beam they are as follows:

| | Grooved. | Open. |
|---|---|---|
| 1. *Fixed at one End.* Weight suspended from the other, | $\frac{l\,w}{b\,d^2\,(1-q\,p^3)} = V$ | $\frac{l\,w}{b\,d^2\,(1-p^3)} = V.$ |
| 2. *Fixed at both Ends.* Weight suspended from the middle, | $\frac{l\,w}{b\,d^2\,(1-q\,p^3)} = V$ | $\frac{l\,w}{b\,d^2\,(1-p^3)} = V.$ |
| 3. *Supported at both Ends.* Weight suspended from the middle, | $\frac{l\,w}{b\,d^2\,(1-q\,p^3)} = V$ | $\frac{l\,w}{b\,d^2\,(1-p^3)} = V.$ |
| 4. *Supported at both* Ends. Weight suspended at any other point than the middle, | $\frac{m\,n\,w}{b\,d^2\,\overline{m+n}\,(1-q\,p^3)} = V$ | $\frac{m\,n\,w}{b\,d^2\,\overline{m+n}\,(1-p^3)} = V.$ |
| 5. *Fixed at both* Ends. Weight suspended at any other point than the middle. | $\frac{m\,n\,w}{b\,d^2\,\overline{m+n}\,(1-q\,p^3)} = V$ | $\frac{m\,n\,w}{b\,d^2\,\overline{m+n}\,(1-p^3)} = V.$ |

Single flanched.

1. ⊥ $$\frac{l\,w}{\frac{b\,d^2\,(1-q\,p^3)\,(1-q)}{(\sqrt{1-q\,p^3}+\sqrt{1-q})^2}} = V.$$

2. 3. 4. 5. For the other conditions of a bar, beam, &c., use the same formula as the above, multiplying the *Value* obtained above by 6, 4, 1, and 1, 5 respectively.

*p and q representing as follows:—the other symbols as in the preceding formulæ.*

$$\frac{\text{depth of groove}}{\text{whole depth of beam}} = p.$$

$$\frac{\text{whole breadth of beam} - \text{width of web}}{\text{whole breadth of beam}} = q.$$

*Transverse Resistance from End Pressure applied Horizontally.*

Wrought Iron.

7·5 feet in length; flanches, 6 × 3·5 inches × ·625 thick; area, 5·5 sq. ins.
50,000 lbs. produced no set.
58,240 " " a set of 1·75 inches.

White Oak.

Rectangle 10 feet in length, 11 × 4·5 inches.
33,600 lbs. gave a deflection of ·375 inch.
50,400 " " " ·5 "
67,200 " " " ·625 "
and with 78,400 " it broke.

## Table of the Transverse Strength of Cast Iron Girders and Beams.

Deduced from the Experiments of Barlow, Hodgkinson, Hughes, Tredgold, &c., reduced to an uniform measure of

*One inch in Depth, one foot in Length, and Supported at Both Ends.*
*The Stress or Weight applied in the Middle.*

| Section of Girder or Beam. | Area of Flanches. Top. | Area of Flanches. Bottom. | Width of vertical web. | Depth of girder. | Width of girder. | Area of section in centre. | Length between supports. | Breaking weight at given length. | Breaking weight at length of one foot. | Strength per square inch of section. | Strength per inch of depth of section. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sq. ins. | Sq. ins. | Inch | Inch. | Inch. | Sq ins. | Feet. | lbs. | lbs. | lbs. | lbs. |
| Equal area of flanch at top & bot. | 1·75 × ·42 = ·735 | 1·77 × ·39 = ·69 | ·29 | 5·125 | 1·77 | 2·82 | 4·6 | 6700 | 30150 | 10708 | 2100 |
| do. | 2·03 × ·515 = 1·045 | 2·03 × ·515 = 1·045 | ·50 | 2·04 | 2·03 | 2·60 | 4· | 4004 | 16016 | 6160 | 3000 |
| do. | 2·02 × ·515 = 1·045 | 2·02 × ·515 = 1·045 | ·51* | 2·02 | 2·02 | 2·59 | 4· | 2369 | 10276 | 3952 | 1900 |
| Area of sec. of top & bot as 1 to 2. | 1·74 × ·26 = ·45 | 1·78 × ·55 = ·98 | ·30 | 5·125 | 1·78 | 2·87 | 4·6 | 7460 | 33300 | 11563 | 2200 |
| do. as 1 to 4. | 1·07 × ·30 = 1·32 | 2·1 × ·57 = 1·2 | ·32 | 5·125 | 2·1 | 3·02 | 4·6 | 8300 | 37350 | 12367 | 2400 |
| do. as 1 to 6. | 2·33 × ·31 = ·72 | 6·67 × ·66 = 4·4 | ·266 | 5·125 | 6·67 | 6·4 | 4·6 | 26100 | 117450 | 18352 | 3550 |
| | | 2·27 × ·46 = 1·044 | ·37 | 5·125 | 2·27 | 2·76 | 4·6 | 8800 | 39600 | 14347 | 2750 |
| | | 1·5 × ·5 = ·75 | ·5 | 3· | 1·5 | 2· | 3·1 | 5208 | 16058 | 8029 | 2650 |
| | | 5 × ·3 = 1·5 | ·365 | 1·56 | 5· | 1·96 | 6·6 | 1120 | 7280 | 3714 | 2350 |
| | 1·5 × ·5 = ·75 | | ·5 | 3· | 1·5 | 2· | 3·1 | 4536 | 13986 | 6993 | 2300 |
| | 5 × ·3 = 1·5 | | ·36 | 1·55 | 5· | 1·96 | 6·6 | 364 | 2366 | 1213 | 750 |
| | | 23·9 × 3·12 = 74·56 | 3·30 | 36·1 | 23·9 | 183·5 | 23·1 | 349440 | 8066240 | 43958 | 1200 |
| | | 1·5 × ·5 = ·75 | ·5 | 4† | 1·5 | 1· | 3·1 | 6480 | 19980 | 19980 | 5000 |
| | 1·5 × ·5 = ·75 | | ·5 | 4† | 1·5 | 1· | 3·1 | 2352 | 7252 | 7252 | 1800 |
| | 4 × 2 = 8 | | 2· | 4· | 4· | 12· | 6· | 5600 | 33600 | 2800 | 700 |
| | 6 × 1·5 = 9 | 8 × 1·5 = 12 | 1·5 | 9· | 8· | 30· | 11·8 | 45300 | 528500 | 17617 | 1900 |
| | 5·1 × 2·33 = 11·88 | 12·1 × 2·07 = 25·04 | 2·08 | 30·5 | 11·1 | 90·8 | 27·6 | 174320 | 4793800 | 52795 | 1700 |

* Horizontal Web.

† Depth of opening, 3 inches.

TABLE OF THE TRANSVERSE STRENGTH OF CAST IRON GIRDERS AND BEAMS. (Continued.)

| SECTION OF GIRDER OR BEAM. | Depth of Beam. | Depth of Metal. | Width of beam. | Dist. between top & bottom base. | Breadth of girder. | Area of section in centre. | Length between supports. | Breaking weight at given length. | Breaking weight at length of one foot. | Strength per square inch of section. | *Value* per inch of depth of section. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inch. | Inch. | Inch. | Inch. | In. | Sq. in. | Feet. | lbs. | lbs. | lbs. | lbs. |
| Rectangular Prism, | 2·012 | 2·012 | ·994 | | — | 2·025 | 5· | 1888 | 9440 | 4662 | 2350 |
| Open Beam. | 2·51 | 1·07 | 1·005 | ·54 | — | 1·98 | 5· | 2468 | 12340 | 6232 | 2450 |
| | 3·01 | 2·01 | ·995 | 1· | — | 2· | 5· | 3084 | 15420 | 7710 | 2550 |
| | 4· | 1·97 | 1·005 | 2·03 | — | 1·98 | 5· | 4353 | 21765 | 10992 | 2700 |
| | 4·04 | 3·01 | ·771 | 1·03 | — | 2·322 | 5· | 5141 | 25705 | 11070 | 2750 |
| | 4·04 | 1·48 | 1·507 | 2·56 | — | 2·23 | 5· | 5147 | 25735 | 11540 | 2850 |
| | 4·07 | 1·56 | 1·525 | 2·51 | — | 2·35 | 5· | 6000 | 30000 | 12089 | 3100 |
| Square Prism, Stress at side, | 1·01 | 1·01 | 1·02 | | — | 1·032 | 5· | 527 | 2635 | 2552 | 2500 |
| Cylinder, | 1·122 | 1·122 | 1·122 | | | ·989 | 5· | 474 | 2370 | 2396 | 2150 |
| Square Prism, Angle up, | 1·443 | 1·443 | 1·443 | | | 1·041 | 2·8 | 449 | 2269 | 2182 | 1500 |
| Versed sine of arch, ·8 | 1· | 1· | 1· | | | 1· | | | 1425 | 1425 | 1400 |
| do. 1·5 | 1· | 1· | 1· | | | 1· | | | 1945 | 1945 | 1900 |
| Versed sine of arch, ·8 | 1· | 1· | 1· | | | 1· | | | 501 | 501 | 500 |
| do. 1·5 | 1· | 1· | 1· | | | 1· | | | 315 | 315 | 300 |

COMPARATIVE RESISTANCE OR STRENGTH OF GIRDERS, BEAMS, &C., OF EQUAL SECTIONAL AREAS AND DEPTHS.

| DESCRIPTION OF GIRDER OR BEAM. | Comparative Strength. |
|---|---|
| Rectangular Beam, | 1· |
| Grooved beam, top and bottom flanches of equal areas, of uniform thickness of metal throughout, and the depth three times the breadth (Tredgold), | 1·16 |
| Single flanched beam, width of flanch five-twelfths of height, width of rib one-half the depth of flanch (Watt and Fairbairn), | 1.27 |
| Open beam, the space one-half the depth, | 1·50 |
| Double flanched beam, area of top flanch, one-sixth of that of bottom; depth of top flanch, one-half of that of bottom; width of bottom flanch, one and a quarter times the depth of the beam (Hodgkinson), | 1·66 |

*To ascertain the Transverse Strength, or the Loads that may be borne by Cast Iron Girders or Beams, of Various Figures and Sections when Supported at Both Ends, the Load applied in the Middle.*

*When the Section of the Girder or Beam is that of a Rectangle, a Grooved, Open, Single or Double Flanched Beam.*

RULE.*—Ascertain the resistance or strength of the rectangular solid, the dimensions of which are the depth and the greatest breadth of the beam, and subtract from it the resistance which would be offered by that part of the beam which is wanting to make it an uniform solid.

NOTE.—This rule is applicable to all cases when the flanch of the beam having the greatest sectional area is set below, when the beam rests upon two supports or is fixed at both ends, or set above when the beam is fixed at one end only.

When the case differs from this, an increase of metal, obtained by a reduction of the *Value* of it, can be estimated for the result of the resistance per square inch of section of beams, of various sections in Table, page 185, 6.

EXAMPLE.—What is the load that will break a Hodgkinson beam, of the following dimensions and 10 feet in length between its supports, the load applied in its middle?

| | | |
|---|---|---|
| Top flanch, | $7 \times 1$ | inch. |
| Bottom flanch, | $21 \times 2$ | " |
| Width of rib, | ·8 | " |
| Whole depth of beam, | 21 | " |
| Area of whole section, | 63·4 | " |
| Dimensions of rectangle, | $21 \times 21$ | " |
| *Hence*, $21^2 \times 21$ | = 9261 | " |

$7 - {\cdot}8 = 6{\cdot}2$ *inches* = *width of space between both extremities of top flanch and rib.* $21 - \overline{2 + 1} = 18$ = *depth of space between top and bottom flanches.*

*Hence,* $18^2 \times 6{\cdot}2 = 2008\,8$.

$21 - 7 = 14$ = *width of space between both extremities of top and bottom flanches.*
$21 - 2 = 19$ = *width of space above bottom flanch.*

*Hence,* $19^2 \times 14 = 5054$.

*Difference,* 7062 8

*And,* $9261 - 7062{\cdot}8 \times 4 \times 500\dagger = 4396400$ = *difference of products of the square of the depth and the breadth of the parts wanting to complete the rectangle multiplied by four times the value of the metal, which* ÷ 10 *for the length* = 439,640 *lbs.*

*In the example given above, the formulæ of various Authors give the following results.*

Hodgkinson.— $\frac{2}{3\,d\,l} \times (b\,d^3 - \overline{(b - b')\,d'^3}) =$ w in tons.

d *representing depth of beam,* d' *depth to bottom flanch,* b *breadth of bottom flanch,* b' *thickness of vertical web, all in inches,* l *length in feet, and* w *weight in tons.*

$\therefore \frac{2}{3 \times 21 \times 10} \times (21 \times 21^3 - \overline{(21 - {\cdot}8) \times 19^3}) = 177{\cdot}55$, *which* $\times$ 2240 = 397,712 lbs.

Fairbairn.— $\frac{2{\cdot}166\,a\,d}{l} =$ w. *a* representing area of bottom flanch.

$\therefore \frac{2{\cdot}166 \times 42 \times 21}{10} = 191{\cdot}1$, *which* $\times$ 2240 = 428,064 *lbs.*

*The utility of this rule, in preference to those of Hodgkinson, Fairbairn, Tredgold, Hughes, and Barlow, is manifest, as in the one case, the *Value* of the metal is considered, and in the other cases, the metal is assumed to be of an uniform value or strength, and when the range in this element, both in weight and cost, render it imperative that in a structure of iron of the highest transverse strength, the weight due to the requirements of dimensions of the lowest transverse strength should not be increased, and contrariwise.

The only variable element not embraced in this rule, is that consequent upon any peculiarity of form of section, as for instance, in that of the Hodgkinson, or like beams, when the area of one flanch, greatly exceeds the rest of the section, and this flanch is placed other than below when the beam rests upon two supports or is fixed at both ends, or than above when the beam is fixed at one end.

† Assumed breaking weight of the metal. In connexion with this, it is to be borne in mind, that the greater the area of the section of the metal, the less its strength, and the longer the beam, the greater the risk of a deflection from a flaw in its structure.

Hughes.— $\frac{2\,a\,d}{l} = \text{W}.$

$\therefore\ \frac{2 \times 42 \times 21}{10} = 176{\cdot}4$, *which* $\times$ 2240 = 395,136 *lbs.*

$\therefore\ \frac{1{\cdot}5\ \text{A}\ d}{2} = \text{W}$, A, *representing area of section.*

$\therefore\ \frac{1{\cdot}5 \times 63{\cdot}4 \times 21}{10} = 199{\cdot}7$, *which* $\times$ 2240 = 447,328 *lbs.*

Barlow.— $\frac{1{\cdot}13\ \text{A}\ d}{l} = \text{W}.$

$\therefore\ \frac{1{\cdot}13 \times 63{\cdot}4 \times 21}{10} = 150{\cdot}4$, *which* $\times$ 2240 = 336,896 *lbs.*

*Again*, experiments upon the breaking weight of girders of English cast iron have given the following results:—

DIMENSIONS OF GIRDERS.

| | 1 and 2. | 3. |
|---|---|---|
| Top flanch, | 3·25 × 1·25 ins. | 4·125 × 1·5 ins. |
| Web, | 1·25 | 1·5 |
| Bottom flanch, | 9· × 1 25 | 15· × 2·25 |
| Whole depth, | 22· | 24·25 |
| Area of bottom flanch, | 11·25 | 33·75 |
| Whole area, | 39·69 sq. ins. | 70·69 sq. ins. |
| Length between supports, | 19· ft. | 30·75 ft. |
| Breaking weight, | 1·116550 lbs. / 2·125350 " | 3·145208 lbs. |

*Breaking Weights calculated by various formulæ.*

| | 1 and 2. | 3. |
|---|---|---|
| By Fairbairn, | 63,213 lbs. | 129,272 lbs. |
| " Hodgkinson, | 94,998 " | 139,082 " |
| " Hughes, | 58,352 " | 119,240 " |
| " Barlow, | 116,323 " | 141,120 " |
| " Rule,* page 187, | 114,337 " | 143,712 " |

COMPARATIVE VALUES OF CAST IRON BARS, HOLLOW GIRDERS, OR TUBES OF VARIOUS FIGURES (English Iron).

| | |
|---|---|
| Square Bar, small, | 1· |
| do, large, | ·75 |
| Round Bar, small, | ·675 |
| Square Tubes, uniform thickness, | 1·075 |
| Rectangular do., do | ·85 |
| Circular do., do | ·90 |
| Elliptic do., do | ·95 |

Determined by the formula, $\frac{\text{A}\ d\ \text{V}}{l} = \text{W}$, A representing area of section, and $d$, depth, *in inches*, $l$, the length in feet, and W, the load that may be borne with safety.

COMPARATIVE STRENGTH OF CAST IRON FLANCHED BEAMS.

| Description of Beam. | Comparative Strength. | Description of Beam. | Comparative Strength. |
|---|---|---|---|
| Beam of equal flanches, | ·58 | Breadth with flanches as 1 to 4·5, | ·78 |
| with only bottom flanch, | ·72 | 1 to 5·5, | ·82 |
| flanches as 1 to 2, | ·63 | 1 to 6, | 1· |
| 1 to 4, | ·73 | 1 to 6·73, | ·92 |
| Average experiment, | ·94 | | |

*The *values* here used, in consideration of the depth and great length of the girders, are reduced to 485 for the first and second cases, and 450 for the third.

**Table of the Transverse Strength of Wrought Iron Girders and Beams.**

**Deduced from the Experiments of Barlow, Fairbairn, Hughes, &c., &c., and reduced to an uniform measure of**

***One Inch in Depth, One Foot in Length, and Supported at Both Ends.***
***The Stress or Weight applied in the Middle.***

| Section of Girder or Beam. | Area of Flanches. Top. | Area of Flanches. Bottom. | Width of vertical web. | Depth of girder. | Breadth of girder. | Thickness of plates. | Area of section. | Length between supports. | Destruc. weight at given length. | Destruc. weight at length of one foot. | Strength per square inch of section. | *Value* for destruct. weight.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sq. ins. | Sq. ins. | Ins. | Ins. | Ins. | Ins. | Sq ins. | Ft. | lbs. | lbs. | lbs. | lbs. |
| Solid, | 2·5 × 1 = 2·5 | 4 × ·38 = 1·52 | ·325 | 8·38 | 4· | | 6·295 | 11· | 12000 | 132000 | 20952 | 2500 |
| | 2·75 × 1 = 2·75 | 4·3 × ·42 = 1·806 | ·38 | 9·42 | 4·3 | | 7·596 | 10· | 22000 | 220000 | 28947 | 3000 |
| " | 2·85 × ·38 = 1·08 | | ·31 | 2·5 | 2·85 | | 1·73 | 4· | 3142 | 12560 | 7260 | 2900 |
| " | | 2·85 × ·38 = 1·08 | ·31 | 2·5 | 2·85 | | 1·73 | 4· | 3008 | 12032 | 6955 | 2750 |
| Riveted, | 2·86 × ·33 = ·944 | 2·86 × ·33 = ·944 | ·66 | 3·7 | 2·86 | | 3·88 | 4· | 14000 | 56000 | 14433 | 3800 |
| " | 5 × ·25 = 1·25<br>2 of 2·25 × 2·25 × ·3 = 2·82 | | ·54 | 2·6 | 5· | | 4·07 | 7· | 3355 | 23485 | 5770 | 2250 |
| do. inverted, | | 5 × ·25 = 1·25<br>2 of 2·25 × 2·25 × ·3 = 2·82 | ·54 | 2·6 | 5· | | 4·07 | 2·3 | 9250 | 20812 | 5113 | 2000 |
| " | 2 of 3·5 × 3·5 × ·5 = 7 | 2 of 3·5 × 3·5 × ·5 = 7 | ·37 | 16· | 7·37 | | 19·92 | 24· | 32000 | 768000 | 38593 | 2400 |
| " | 2 of 2·125 × ·28 = 1·19 | 2 of 2·125 × ·30 × 1·29 | ·25 | 7· | 4·23 | | 4·23 | 7· | 24380 | 170660 | 40345 | 5800 |
| " | | | | 3· | 1·9 | ·03 | ·29 | 3·9 | 672 | 2520 | 8689 | 2850 |
| " | | | | 3· | 1·95 | ·061 | ·60 | 3·9 | 2520 | 9450 | 15750 | 5200 |
| " | | | | 5·8 | 3·8 | ·065 | 1·24 | 7·6 | 3156 | 23670 | 19089 | 3200 |
| " | | | | 6· | 3·9 | ·1325 | 2·60 | 7·6 | 9976 | 74820 | 28777 | 4600 |
| " | | | | 6· | 4· | ·1325 | 2·62 | 7·6 | 10080 | 75600 | 28855 | 4700 |
| " | | | | 24· | 15· | ·124 | 9·60 | 30· | 12500 | 375000 | 39063 | 1600 |
| " | | | | 23·75 | 15·5 | ·272 | 21·20 | 30· | 51200 | 1536000 | 72452 | 3000 |
| " | | | | 24· | 15·5 | ·525 | 40·92 | 30· | 128000 | 3867000 | 94648 | 3900 |
| " | | | | 24· | 16· | ·525 | 41·45 | 30· | 128800 | 3864000 | 93221 | 3900 |
| " | | | | 30· | 24· | ·75 | 87·75 | 45· | 291200 | 13104000 | 149333 | 4900 |
| | | | | Feet. | Feet. | | | | | | | |
| " | 9·6 × ·075 = ·72 | 9·6 × ·0743 = ·713 | | 9·5 | 9·5 | ·0743 | 2·86 | 17·5 | 3738 | 65415 | 22872 | 2400 |
| " | 9·6 × ·252 = 2·419 | 9·6 × ·075 = ·72 | | 9·5 | 9·5 | ·074 | 4·36 | 17·5 | 8273 | 146528 | 33607 | 3450 |
| " | 9·6 × ·076 = ·727 | 9·6 × ·142 = 1·363 | | 9·5 | 9·5 | ·076 | 3·54 | 17·5 | 3788 | 66290 | 18723 | 1950 |
| " | 9·6 × ·142 = 1·363 | 9·6 × ·076 = ·727 | | 9·5 | 9·5 | ·076 | 3·54 | 17·5 | 7148 | 125090 | 35619 | 3700 |
| " | 9·25 × ·149 = 1·378 | 9·25 × ·269 = 2·488 | | 18·25 | 9·25 | ·059 | 6·03 | 17·5 | 6812 | 119210 | 19768 | 1050 |

* The above and preceding results are deduced from girders of the length given; hence, when the length is less, the breaking weight may be increased, in consequence of the increased stability of the girder. These results are very conclusive of the correctness of the formula used, viz: $\frac{A\,d\,v}{l}$, as will be seen in the experiments here given.

TABLE OF THE TRANSVERSE STRENGTH OF WROUGHT IRON GIRDERS AND BEAMS. (Continued.)

| SECTION OF GIRDER OR BEAM. | Area of Flanches. Top. | Area of Flanches. Bottom. | Width of vert'l web. | Depth of girder. | Breadth of girder. | Thickness of plates. | Area of section. | Length between supports. | Destructive weight at given length. | Destructive weight at length of one foot. | Strength per square inch of section. | *Value* for destructive weight. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sq. ins. | Sq. ins. | In | Ins. | Ins. | Ins. | Sq in. | Ft. | lbs. | lbs. | lbs. | lbs. |
| | 9·25 × ·269 = 2·488 | 9·25 × ·149 = 1·378 | | 18·25 | 9·25 | ·059 | 6·03 | 17·5 | 12188 | 213290 | 35371 | 1900 |
| | 2·25 × ·26 = ·585 | 2·25 × ·26 = ·585 | | 15· | 2·25 | ·131 | 5·10 | 24· | 17600 | 452400 | 88700 | 5500 |
| | 1 × ·282 = ·282 | 1 × ·116 = ·116 | | 8· | 1· | ·067 | 1·47 | 11· | 12254 | 123794 | 84214 | 16300 |
| | 24·* | 12·8 | | 54· | 2·92 | | 45·82 | 75· | 125912 | 9443400 | 206096 | 3800 |
| Elliptical,† | | | | 24· | 16· | ·375 top, ·25 bot., ·125 side | | ·30 | 62720 | 188160 | | |
| " | | | | 36· | 24· | ·562 top, ·375 bot., ·25 side | | ·30 | 231465 | 6943950 | | |
| Tubes, | | | | 12· | 12· | ·0408 | 1·40 | 17· | 2000 | 41200 | 31571 | 2600 |
| | | | | 24· | 24· | ·095 | 7·13 | 31·27 | 9550 | 298629 | 41743 | 1725 |
| Elliptical, | | | | 14·62 | 9·25 | ·0416 | 1·56 | 17· | 2150 | 36550 | 23430 | 1600 |
| | | | | 15· | 9·75 | ·143 | 5·56 | 17·5 | 15900 | 278250 | 50045 | 3300 |

* Thickness of plates, bottom, ·156; top, ·147; sides, ·090. Area of bottom, 8·8 ins.

† The lateral strength of this was ascertained to be 38080, or $\frac{1}{3}\frac{9}{1}$ of its vertical strength. The ultimate deflection was 2·75 ins.

## RESULTS OF EXPERIMENTS UPON THE TRANSVERSE STRENGTH OF WROUGHT IRON ELLIPTICAL TUBES, English Iron, Fairbairn.

*Distance between the supports* 30 *feet; weight suspended in the middle.*

| Depth of tube. | Breadth of tube. | | Thickness of metal in inches. | | | Breaking weight. |
|---|---|---|---|---|---|---|
| Ft. | Ft. | ins. | Top. | Bottom. | Side. | lbs. |
| 2 | 1 | 4 | 3-8 | $\frac{1}{4}$ | 1-8 | 62,720 |
| 3 | 2 | | 9-16 | $\frac{3}{8}$ | 3-16 | 231,465 |

The ultimate deflexion was for the first, $2\frac{3}{4}$ inches.

The above and many of the preceding results are deduced from girders of the length of from 20 to 30 feet; hence, when the length is less, the breaking weight may be increased, in consequence of the increased stability of the girder.

These results are very conclusive of the correctness of the formula used, viz: $\frac{\text{A}\, d\, \text{V}}{l}$, as will be seen in the cases here given, in the 11th and 19th cases, where the relations between breadth, depth, and thickness are nearly identical, and in the 12th and 16th cases, where the

relations between breadth are the same, but the thickness and consequent area differ.

*To Ascertain the Transverse Strength, or the Loads that can be borne by Wrought Iron Girders, Beams, or Tubes, of Various Figures, and Sections when Supported at Both Ends, the Load applied in the Middle.*

RULE.—Divide the product of the area of the section, the depth, and the *Value* for the construction from the preceding table, by the length in feet, and the quotient is the destructive weight in pounds.

NOTE 1.—The rule given at page 187 for cast iron girders, &c., &c., will also apply here, when the metal is of such thickness as to give the girder, &c., full resistance to lateral flexure, and when the construction is such as to bring the stress upon the tension and compression of the metals, and not upon the rivets.

2. In determining the *Value*, the proportions of the construction in its flanches, width, and depth, &c., must be observed as well as the character of it.

3. The *Values* here given are based upon experiments with English iron.

EXAMPLE 1.—What is the load that will destroy a wrought iron solid grooved beam of the following dimensions:—

| | | |
|---|---|---|
| Top flanches, | $3 \times 1{\cdot}25$ | ins. |
| Bottom flanch, | $4 \times {\cdot}5$ | " |
| Width of web, | ${\cdot}4$ | " |
| Depth of beam, | $9{\cdot}$ | " |

$3 \times 1{\cdot}25 + \overline{4 \times {\cdot}5} = 3{\cdot}75 + 2 = 5{\cdot}75$ *inches, which* $+ 9 - \overline{1{\cdot}25 + {\cdot}5 \times {\cdot}4} = 2{\cdot}90 = 8{\cdot}65$ *inches = area of section.*

$$\textit{Then,} \quad \frac{8{\cdot}65 \times 9 \times 3000}{10} = 23{,}355 \textit{ lbs.}$$

EXAMPLE 2.—What is the load that will destroy a wrought iron plate beam of the following dimensions, and 10 feet in length between the supports?

| | | |
|---|---|---|
| Top flanch, | two of $3{\cdot}5 \times {\cdot}5 \times {\cdot}5$ | ins. |
| Bottom flanch, | two of $3{\cdot}5 \times {\cdot}5 \times {\cdot}5$ | " |
| Width of web, | ${\cdot}5$ | " |
| Depth of beam, | $17$ | " |

$3{\cdot}5 \times {\cdot}5 \times 2 + \overline{(3{\cdot}5 - {\cdot}5 \times {\cdot}5 \times 2) \times 2} = 13$ *inches, which,* $+ \overline{17 \times {\cdot}5} = 21{\cdot}5$ *inches = area of section.*

$$\textit{Then,} \quad \frac{21{\cdot}5 \times 17 \times 2400}{10} = 87{,}720 \textit{ lbs.}$$

EXAMPLE 3.—What is the load that will destroy a wrought iron rectangular tube of the following dimensions, and 10 feet in length between the supports?

| | | |
|---|---|---|
| Depth, | $25{\cdot}00$ | ins. |
| Breadth, | $16{\cdot}00$ | " |
| Thickness of metal, | ${\cdot}30$ | " |
| Area of section of metal, | $29{\cdot}64$ | " |

$$\textit{Then,} \quad \frac{29{\cdot}64 \times 25 \times 3500}{10} = 259{,}350 \textit{ lbs.}$$

*Formulæ for Beams and Tubes of Wrought Iron.*—(Fairbairn.)*

Solid Beams, $\frac{2800 \text{ A } d}{l} = \text{W}.$

Plate do., $\frac{2912 \text{ A } d}{l} = \text{W}.$

Cylindrical Tubes, $\frac{1792 \text{ to } 2800 \text{ A } d}{l} = \text{W}.$

Elliptical do., $\frac{1680 \text{ to } 5510 \text{ A } d}{l} = \text{W}.$

A *representing area of section, d the depth in inches, and l the length in feet.*

Hodgkinson.

Rectangular Beams, $\frac{60{,}000 \text{ to } 90{,}000 \ (b\, d^3 - b'\, d'^3)}{3\, l\, d} = \text{W}.$

Cylindrical Tubes, $\frac{3{\cdot}1416 \times 22{,}500 \text{ to } 35{,}500}{\text{A } l} (r^4 - r'^4) = \text{W}.$

Elliptical do., $\frac{3{\cdot}1416 \times 29{,}000 \text{ to } 37{,}000 \ (c\, b^3 - c'\, b'^3)}{\text{A } l} = \text{W}.$

*v, b', and d, d' representing the external and internal breadths and depths; r and r', the external and internal radii; and c c', and b b', semi-conjugate and semi-transverse diameter in inches; and l, the length in inches.*

Comparative Values of Wrought Iron Bars, Hollow Girders, or Tubes of Various Figures (English Iron).

| | |
|---|---|
| Square Bar, | 250 |
| Round do., | 195 |
| Rectangular Tubes, plates at top and bottom thick, at sides thin, | 425 |
| *Welded Tubes without Rivets.* | |
| Rectangular uniform thickness, | 375 |
| Circular do., | 325 |
| Elliptic do., | 350 |
| Circular Tubes riveted, | 190 |
| Rectangular do., | 280 |
| Elliptic do., | 250 |
| Flanched Beams, | 240 |
| Plate do., | 320 |

Determined by the formula, $\frac{\text{A } d \text{ V}}{2} = \text{W}.$

* See Report of Commissioners on Railway Structures, 1849.

(To be Continued.)

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### *Aluminum Bronze.*

They are now testing at Manchester, the new bronze formed of 10 parts of aluminum and 90 parts of copper, to which M. Christofle called attention long ago. Its hardness is such that in a lathe making 2000 revolutions per minute, it requires six times as long to drill it as any other metal does.—*Cosmos*, September, 1860.

For the Journal of the Franklin Institute.

## *On the Economy resulting from Expansion of Steam.*

By Robert H. Thurston.

The experiments of Chief Engineer Isherwood at the Brooklyn Navy Yard, those now in progress on board the *Michigan*, at Erie, Pa., and others lately tried, seem to be making converts to the doctrine that the principle of the expansion of steam is of no practical value. I would like to offer a word or two in regard to these experiments, and also a few facts which seem to me to furnish quite as good evidence on the other side of the question.

The experiments on the engine of the *Michigan* show the consumption of fuel to be actually greater in proportion to the power evolved when "cutting off" at ·354, than when "following" full stroke.

At the time of the experiment under the first-named circumstances, however, the engine made but *nine revolutions per minute*. It is well known among engineers that a high speed of piston is required to enable an engine to work economically, *especially* when it is intended to obtain the full benefit of expansion. At this speed, the steam must have been refrigerated very effectually.

A writer, referring to the above experiment, in a late number of a journal devoted to engineering interests, remarks that a great gain by the use of a "cut-off" is all "moonshine," and, "engineers and scientific men have, for the last eighty years, subscribed to the greatest of fallacies," which assertion is supposed to be proved by *this single experiment*. As rebutting evidence, however, other well-known experiments of Mr. Isherwood himself may be adduced.

In his experiments on the smithery engine, at the Navy Yard, he found that by cutting off at ·22, sixteen per cent. was gained over its full stroke performance. The gain in economy, certainly, fell far short of that called for by theory, but it was a very perceivable gain, notwithstanding. That the engine was in a most wretched condition, was proved by its extraordinary consumption of coal (15 pounds per H. P. per hour).

In the same volume in which are given the details of this latter experiment, is also given the account of another experiment on a different engine, in which the gain by cutting off at ·28, amounts to nearly *thirty per cent.*

In this case, the consumption of coal at full stroke was 5·56 pounds per horse power, per hour, a vast improvement over the previous one, even when the difference in boilers is taken into account.

If, then, even these engines exhibit so great a gain, what may we not expect from engines in which the evils consequent upon uncovered pipes and cylinders, slow speed, long and contracted steam passages, slow closing of opening, and the many other circumstances especially detrimental to "cut-off engines," are avoided. The nearer we make our practice conform to theory, by providing against the interference of circumstances unrecognised by our theory, the nearer will our

practical results conform to our theoretical deductions. Mariotte's law provides that no heat shall be abstracted from the expanding vapor; hence, experiments conducted in a refrigerator should hardly be expected to be taken as proof of the falsity of that law. The unexpected discrepancy between theory and the result of experiment, should only render engineers more pains-taking in providing against adverse circumstances.

The most economical engine, not *specially* adapted to the use of steam expansively, that I have had occasion to test, is now running in this city. It was built by a Wilmington firm, and its valve is of the "long D" variety.

The engine runs night and day the week through. The engine room is very hot. Temperature of feed probably averages 150°. The steampipe is short, and the engine runs at a tolerably high speed. The circumstances all favor economy. The consumption of coal is *four* pounds per H. P. per hour.

The engine formerly required twenty per cent. more fuel than at present. The saving was effected by giving the valve more lap, and carrying steam high enough to bring the engine up to speed. Fig. 1, Plate IV, is an indicator card, taken after the change was effected. The change in direction of the steam-line at *a*, shows the point of cut-off.

The most economical engine of which I have knowledge, *built with special reference to the use of steam expansively*, is one of a class of engines now coming rapidly into use, known as the "Greene engine," and was built at Providence, R. I. It is running in circumstances very similar to the last mentioned, and is consuming *two and a quarter* pounds coal to the H. P. per hour. The great difference between the two engines in view of the amount of coal required, is readily accounted for by the vast difference in construction. An engraving of an engine of the latter form is given in Weissenborn's "*American Engineering Illustrated.*"

The steam-chest in this engine is very large, and acts to some extent as a steam jacket. The valves are four in number, and are perfectly *flat*, thus avoiding liability to leak, either from wear or by warping under the action of the steam. They are placed at the ends of the cylinder, thus securing short steam passages, and are closed either by a spring or falling weight, thus obtaining a rapid movement. The regulator acts by determining the point of cut-off, which may vary from nearly full stroke to any fractional part of the stroke, and steam is thus let into the cylinder at nearly the boiler pressure. The cylinder is carefully covered to prevent radiation, and the *ensemble*, although probably capable of improvement, is, perhaps, the best engine now manufactured.

The comparison of the last two engines represents fairly, I think, the relative merits of the two classes. The *average* consumption of coal by engines as usually built, is probably between six and seven pounds per H. P. per hour, while that of engines built like the one last referred to, is certainly not above *three and a half* pounds with engines

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Fig. 5.
Steamer Armenia. Steven's Cut-off.
Fig. 7.
3 lbs. per H.P. per hour.
Fig. 6.
Arnold's attachment to the above.
Steam in Boiler 105.
Fig. 4.
Greene Engine.
18 in. Cyl. 4 Ft. Str.
101
50 Rev.
H.P. = 226 3/4
82
56 lbs.
Fig. 1.
a
H.P. 58
Coal 4 lbs. per H.P. per hour.
Fig. 2.
Greene Engine.
Boiler Pressure 63
4 lbs. Coal-dust per H.P. per hour.
Fig. 3.
Greene Engine.
Boiler Pressure 61.
H.P. 54.
3 lbs. Coal per H.P. per hr.

of fifty horse power and upward. Figs. 2, 3, and 4, Plate IV, are indicator cards from Greene engines built at Providence, and exhibit tolerably well the merits of the machine.

The Cornish engine is universally acknowledged to be the most economical engine in the world, and in it the principle of expansion is carried to the greatest extent. One instance at least has been known where the consumption of coal was *less than a pound and a half*, and the *average* of these engines is but little over *two and a half* per H. P. per hour.

An English firm is building *marine engines*, which use about two pounds only per H. P. per hour, and in them the principle of expansion is carried almost to excess.

An excellent example showing the advantage of a good opening and the rapid closing of a cut-off valve, is presented by the working of the engine of the steamer *Armenia*, on the Hudson. The engine, a 40-inch cylinder of 14 ft. stroke, was built with "Steven's valve gear." Some few months since, she was fitted with E. R. Arnold's "Attachment," at a cost which certainly could not amount to $500. Figs. 5 and 6, Plate IV, are cards taken before and after the change. The effect of this added improvement was to decrease the consumption of coal more than a ton on each trip from New York to Albany. The point of cut-off is also now adjustable to any point from 4 feet to full stroke. Fig. 7, Plate IV, is from a fine engine having a "Sickle's cut-off," which was built and is now running at Providence.

Philadelphia, January, 1861.

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For the Journal of the Franklin Institute.

*Strength of a Beam Fixed at Both Ends.* By THEO. COOPER, C.E.

The strength of such a beam, when loaded at the centre, is stated by many to be, when compared with a similar beam *supported* at both ends, as 3 : 2.

By *theory*, however, it should be as 4 : 2, or 2 : 1.

In the case of a single beam, owing to the difficulty of perfectly fixing the ends, this theoretical result is not obtained; but there is a practical case in which we think it could be obtained, and would be of great importance:—that of a continuous beam extending over several points of support.

Let A B be such a beam, extending over several equidistant supports, *a*, *b*, *c*, &c., and loaded at the centre of the openings with weights, W.

The reactions at *a*, *b*, *c*, &c., will also be equal to W, and the convex portions, *o m*, of the beam will be equal and similar to the concave portions, *m n*; since both are acted upon by the same forces.

Evidently at the sections, *o*, *m*, *n*, of the beam, there will be no

strain of compression or extension, and were the beam separated at these points and the parts suspended from each other, the relation of the forces in the beam would not be altered.

This would divide the beam, A B, into a number of beams, with a length equal to one-half the opening, *a b*, and supported at the ends. The strength of each of these, representing the strength of A B, would be *twice* that of separated beams spanning the openings, *ab*, *bc*, &c.

We see, moreover, that the beam thus loaded would break at both the *centre* and *supports*, *simultaneously*.

If, however, we suppose the beam, A B, to be loaded *uniformly* over its whole length, the *reaction* then being greater than the force acting between the supports reduced to the centre, the relation of the forces will be different, and we shall have as follows:—

Representing the strain at the centre of the opening by 1,
that for the strain over the supports will be 2,
and that for the centre of a detached beam of the same span,
will be 3.

A beam thus loaded would break *first* over the supports, and *then* at the centre; and its strength would be to that of a *supported* beam, of the *same* span and load, as 3 : 2. (Moseley says as 3 : 1, but he *assumes* it to break at the centre.)

The points, *o*, *m*, *n*, will be at a distance of 0·26289 of the opening from the supports.

This last case may be applied to a bridge continued over several piers, and supporting a distributed load, as a train of locomotives.

As we gain 50 per cent. in strength by thus continuing even a girder of uniform chords over the piers, we see the importance of considering these facts.

And in proportioning the chords to the strains, we would have very different results from the case of a single span; for in the parts, *o m*, of the girder, the position of the compressive and extensile forces, would be the reverse of that for the part *m n*; the chords should be the strongest over the piers, and decrease towards *o* and *m*, and then again increase to the centre, where the strength must be to that at the piers as 1 : 2.

When only one span is loaded, our assumption of a distributed load may still be considered as true, by making a proper application of a system of counter braces, to prevent the uprising of the unloaded spans.

When we have a girder extending over but two or three openings, our statements are subject to modification.

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## *On the Preservation of Platinum Crucibles.*

From the Lond. Chemical News, No. 49.

In connexion with some sensible remarks upon the use of sand in cleaning platinum crucibles,—a practice which, with Berzelius ("*Lehrbuch der Chemie*," 1841, *4th Aufl.*, *p.* 516), he heartily commends, urging that it should be employed every time that a crucible is used,

—Erdmann explains the cause of the grey coating which forms upon platinum crucibles whenever they are ignited in the flame of Bunsen's gas-burner.

This coating has given rise to much annoyance and solicitude among chemists. Indeed, it has often been asserted that the use of Bunsen's burner is unadvisable in quantitative analysis, since, by means of it, the weight of platinum crucibles is altered, and the crucibles themselves injured. The coating is produced most rapidly when the crucible is placed in the inner cone of the flame, and the more readily in proportion as the pressure under which the gas is burned is higher. Having found it advantageous to maintain, by means of a special small gas-holder, a pressure of four or five inches upon the gas used in his own laboratory, Erdmann has observed that the strong gas flame thus afforded immediately occasions the formation of a dull ring upon the polished metal placed in the inner flame, this ring being especially conspicuous when the crucible becomes red hot; it increases continually, so that after long-continued ignition the whole of the bottom of the crucible will be found to be grey, and with its lustre dimmed.

This ring is caused neither by sulphur, as some have believed, nor by a coating of inorganic matter, but is simply a superficial loosening of the texture of the platinum in consequence of the strong heat; whence it first of all appears in the hottest part of the flame.

In conjunction with Pettenkofer, Erdmann instituted several experiments, which have left but little doubt that the phenomenon depends upon a molecular alteration of the surface of the metal. If a weighed polished crucible be ignited for a long time over Bunsen's lamp, the position of the crucible being changed from time to time in order that the greatest possible portion of its surface shall be covered with the grey coating, and its weight be then determined anew, it will be found that this has not increased. The coating cannot be removed either by melting with bisulphate of potash or with carbonate of soda. It disappears, however, when the metal is polished with sand; the loss of weight which the crucible undergoes being exceedingly insignificant, a crucible weighing 25 grammes having lost hardly half a milligramme. When the grey coating of the crucible is examined under the microscope, it may be clearly seen that the metal has acquired a rough, almost warty surface, which disappears when it is polished with sand. Platinum wires which are frequently ignited in the gas flame, —for example, the triangles which are used to support crucibles,— become, as is known, grey and brittle. Under the microscope, they exhibit a multitude of fine longitudinal cracks, which as the original superficial alteration penetrates deeper, become more open, or, as it were, spongy, until finally the wire breaks.

If such wire is strongly and perseveringly rubbed with sand, the cracks disappear, and the wire becomes smooth and polished; for the grains of sand, acting like burnishers, restore the original tenacity of the metal, very little of its substance being rubbed off meanwhile. The loosening effect of a strong heat upon metals is beautifully ex-

hibited when silver is ignited in the gas flame; a thick polished sheet of silver immediately becoming dull white when thus heated. Under the microscope, the metal appears swollen and warty. Where it has been exposed to the action of the inner flame along its circumference, this warty condition is visible to the naked eye. A stroke with the burnishing-stone, however, presses down the loosened particles and reproduces the original polish. This peculiar condition which the surface of silver assumes when it is ignited, is well known to silversmiths; it cannot be replaced by any etching with acids; and it must be remembered that what is dull white in silver appears grey in platinum.

If each commencement of this loosening is again destroyed, the crucibles will be preserved unaltered, otherwise they must gradually become brittle. Crucibles of the alloy of platinum and iridium are altered like those of platinum when they are ignited. It is, however, somewhat more difficult to reproduce the original polish of the metal by means of sand, as might be expected from the greater hardness of the alloy.

The sand used should be well worn. When examined under the microscope, no grain of it should exhibit sharp edges or corners; all the angles should be obtuse.—*Journ. fur praktische Chemie*, lxxix, 117.

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For the Journal of the Franklin Institute.

## *Triangular Beams.* By Prof. D. Wood.

As I find that the statements of different authors respecting the strength of triangular beams are very conflicting, I propose in this article to make an analytical investigation of the problem, and compare the results with experiment.

The problem may, for convenience, be thus stated:

*A triangular prism being supported at its extremities; it is required to ascertain how great a weight it will sustain at the middle point without fracture.*

But as we know that the strength of a beam depends upon its transverse sections, it will only be necessary to investigate the *resistance of a triangular section.*

To introduce the several points which I wish to discuss, I shall make extracts from various authors. I find in Olmstead's Natural Philosophy, p. 153 (or p. 107 of Prof. Snell's edition), the following statement:

"*A triangular beam is twice as strong when resting on its broad base as when resting on its edge.*

I would pass this statement with the remark that the deduction is founded on Galileo's theory, which is known to be false, were it not for the fact that many think that the statement is correct; also that beams made of some kinds of material are stronger in the former than in the latter position, but not for the reasons given by Olmstead.

1. Suppose the beam is made of wood.

The resistance of wood to compression is nearly the same as for ex-

tension. If it were the same, the beam would be equally strong in either position; for the same strain comes upon the edge, whether it be up or down.

But if it resist more to tension than compression it would be stronger *when resting on its edge*, and *vice versa*. These conclusions are fully sustained by experiment. Mr. Couch made some experiments on triangular (Canadian) oak beams, fixed by one end and loaded at the other. The mean of four experiments gave,

with the angle upward, . 315 lbs.
" downward, . 348 "

(See Barlow's Strength of Materials, p. 118.)

2. Suppose the beam is made of cast iron.

Cast iron will resist about 6 times as much to compression as to tension (see Mahan's Civil Engineering, p. 82). Hence, if we suppose the yielding to be at the angle, the beam will be six times as strong when the angle is upward as when it is downward. I know of no experiments on triangular cast iron beams, but Barlow has made experiments which confirm us in our conclusion (see his Strength of Materials, p. 337; also, Mahan, p. 88). In a similar manner we might determine the relative strength of a beam in the two positions if made of any other material. If the beam is fixed at one extremity instead of being supported, then the preceding conclusions would be reversed.

I now propose *to find the strongest trapezoidal beam which can be cut from a given triangular one.*

To investigate this case, we will resort to the fundamental expression for the resistance of beams subjected to a transverse strain.

Let R = the ultimate resistance of a unit of section to compression or extension.

$d_1$ = distance of the farthest fibre from the neutral surface.

I = moment of inertia of the section about an axis through its centre of gravity and parallel to the base.

We then have for the moment of resistance

$$\frac{R\,I}{d_1}$$

[See Mosley's Mechanics and Engineering Eq., (637).]

Let A B C be the given triangle.

A B E D the required trapezoid.

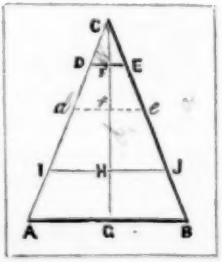
Let $b$ = A B. $v$ = D E.

$a$ = C G = longest altitude of A B C. $w$ = C F.

H = centre of gravity of the trapezoid A B E D.

$d_1$ = F H. (2) $z$ = C H = $d_1 + w$.

I J is the neutral axis of the trapezoid.




To find C H, we have, from the equation of moments, origin at C,

$$\tfrac{1}{2}\,a\,b\,\tfrac{2}{3}\,a = \tfrac{1}{2}\,v\,w\,\tfrac{2}{3}\,w + \frac{b+v}{2}\,(a-w)\,z.$$

(3) $$\therefore \qquad z = \tfrac{2}{3}\,\frac{a^2 b - v\,w^2}{(b+v)\,(a-w)}.$$

(4) From the similarity of triangles we have

$$v : w :: b : a \qquad \therefore \quad w = \frac{a}{b}\, v. \tag{4}$$

From (2) and (3) we have $d_{,} = z - w = \frac{2}{3}\,\frac{a^2 b - v\, w^2}{(b+v)\,(a-w)}\, w$;

by substituting $w$ from (4) we have

$$d_{,} = \tfrac{1}{3}\,\frac{a}{b}\,\frac{2\,b^2 - b\,v - v^2}{b+v}. \tag{5}$$

The moment of inertia about I J as an axis is equal to the moment of inertia about D E *minus* the area A B E D $\times$ F H$^2$.

Let F$f = x$. $\qquad d\,e = y$.

Then from the similar triangles C D E and C $d$ $e$ we have

$$y : b :: x + w \text{ or } x + \frac{a}{b}\, v : a.$$

$$\therefore \quad y = \frac{b\,x + a\,v}{a}.$$

Hence, the moment of inertia about D E as an axis is

$$\int_0^{x=a-w} x^2 y\, dx = \int_0^{\frac{a}{b}(b-v)} \frac{x^2}{a}\,(b\,x + a\,v)\,dx = \frac{b}{a}\left[\frac{x^4}{4}\right]_0^{\frac{a}{b}(b-v)} + \left[\frac{v}{3}x^3\right]_0^{\frac{a}{b}(b-v)}$$

$$= \frac{a^3}{12\,b^3}\,(3\,b^4 - 8\,b^3 v + 6\,b^2 v^2 - v^4). \tag{6}$$

Area of the trapezoid is

$$\frac{b+v}{2}\,(a-w) = \frac{a}{2\,b}\,(b^2 - v^2),$$

which multiplied by F H$^2 = d_{,}^2$ gives

$$\frac{1}{18}\,\frac{a^3}{b^3}\,(b^2 - v^2)\left(\frac{2\,b^2 - b\,v - v^2}{b+v}\right)^2, \tag{7}$$

which subtracted from (6) gives the moment of inertia about I J; which by reduction will become

$$\text{I} = \frac{1}{36}\,\frac{a^3}{b^3}\left[b^4 - v^2(8\,b^2 - 16\,b\,v + 9\,v^2) - 8\,\frac{b-v}{b+v}\,v^4\right]$$

$$= \frac{1}{36}\,\frac{a^3}{b^3}\left[\frac{b^5 + b^4 v - 8\,b^3 v^2 + 8\,b^2 v^3 - b\,v^4 - v^5}{b+v}\right]. \tag{8}$$

If $v = 0$ this becomes $= \frac{1}{36}\,a^3 b$, which is the moment of inertia of a triangle about one axis passing through its centre of gravity and parallel to its base.

By substituting (5) and (8) in (1) we have

$$\text{R}\,\frac{\text{I}}{d_{,}} = \frac{1}{12}\,\text{R}\,\frac{a^3}{b^3}\left[\frac{b^5 + b^4 v - 8\,b^3 v^2 + 8\,b^2 v^3 - b\,v^4 - v^5}{2\,b^2 - b\,v - v^2}\right] \tag{9}$$

which is to be a maximum;

∴ we have

$$(10)\quad \frac{du}{dv} = 0 = v^6 + 2bv^5 - 5b^2v^4 - 8b^3v^3 + 19b^4v^2 - 10b^5v + b^6.$$

By discussing this equation we find that it has three roots, each equal $b$, which gives a minimum. Divide Eq. (10) by $(v-b)^3$, and we have

$$(11)\quad v^3 + 5bv^2 + 7b^2v - b^3 = 0$$

$$(12)\quad \text{make}\quad v = \frac{z - 5b}{3} \text{ and (11) becomes}$$

$$x^3 - 12b^2z - 92b^3 = 0,$$

which solved by Cardan's formula gives

$$z = 5{\cdot}39118\,b, \quad \text{and this in (12) gives}$$

$$(13)\quad v = 0{\cdot}13093\,b, \quad \text{and this in (4) gives}$$

$$(14)\quad w = 0{\cdot}13093\,a.$$

By substituting $v$, Eq. (13), in (9) it becomes

$$(15)\quad \text{R}\frac{\text{I}}{d} = 0{\cdot}545625\ \text{R}\frac{a^2b}{12}.$$

Making $v = 0$ in (9), we have the moment of the full triangular

$$(16)\quad \text{section} = 0{\cdot}5\ \text{R}\frac{a^2b}{12}.$$

Taking Eq. (16) from (15) we have

$$0{\cdot}04562\ \text{R}\frac{a^2b}{12}.$$

Hence, *if the angle of the prism be taken off to* ·13 *of its depth, the prism will be* $0{\cdot}04562\ \text{R}\frac{a^2b}{12}$ *stronger*, or 1·09125 *times as strong, which is a gain of over* 9 *per cent.*

Haupt, in his valuable work on Bridge construction, p. 51, says: "It is found that the prism becomes one-thirty-seventh part stronger when the angle is taken off to one-tenth of the depth."

By making $v = {\cdot}1$ in (9) it becomes

$$(17)\quad 0{\cdot}54385\ \text{R}\frac{a^2b}{12},$$

which is $0{\cdot}04385\ \text{R}\frac{a^2b}{12}$ stronger than the full section. Dividing this by (16) we find that it is 0·0877, or more than one-twelfth part stronger.

Barlow, in his Strength of Materials, p. 116, intimates "that it is the commonly received notion, that if the vertex, or upper edge of a triangular prismatic beam, be cut off to one-third the depth, the piece will be stronger than before."

To compare this "received notion" with theory, make $v = \frac{1}{3}$ in (9), and we have

$$(18)\quad 0{\cdot}465608\ \text{R}\frac{a^2b}{12},$$

which being divided by (16) gives 0·93101, or according to theory

*this trapezoid beam should be only ninety-three-hundredths as strong as the triangular one from which it is cut.*

This conclusion is sustained to a remarkable degree of exactness by the experiments of Mr. Couch as given by Barlow, p. 118.

The mean of seven experiments made by Mr. Couch on the strength of triangular oak beams with the angle upward, is 306 lbs.

The mean of two on trapezoidal beams with the narrow side up, made from triangular prisms of the same size used in the preceding experiments by cutting off the angle to one-third the depth, is 284·5 lbs., which is only four-hundredths lb. less than ·93 of 306 lbs.

By comparing expressions (15), (16), (17), and (18), and calling the strength of the triangular beam unity, we have the following results:

| | |
|---|---|
| Strength of the triangular beam, . . . | 1. |
| Strength of the same beam if the edge be cut off to ⅓ the depth, . | 0·93101 |
| " " " " 1-10 " | 1·0877 |
| " " " " so as to give a maximum strength, . . . | 1·0912 |

In order to explain this apparent paradox, we must remember that the condition is not that the triangular beam shall be fractured completely through, but that it shall not be fractured at all. Now the *greatest strain* comes upon the edge, but there is only one fibre there to resist it; but after a small portion of the edge is removed there are many fibres along the line D E at the same distance from the neutral surface, each of which will sustain the same part of the *greatest strain*.

If the triangular beam were loaded so as to just commence fracturing at the edge, we might increase the load 9 per cent. and increase the fracture to only thirteen-hundredths of its depth; but if the load be increased beyond this amount, it will break the beam completely in two.

Again, Haupt says (p. 51), "It is found that the strength of the triangular prism is to that of a rectangular prism having the same base and altitude, as 339 : 1000, or nearly as 1 : 3."

The moment of resistance of the triangular section is, Eq. (16),

$$\frac{1}{24} \text{R } a^2 d.$$

The moment of resistance of a rectangular section is well known to be (found from (1)),

$$\frac{1}{6} \text{R } a^2 d.$$

Hence, theoretically, they are to each other as 1 : 4.

I will close this article by comparing the maximum trapezoidal beam with a rectangular one having the same base and altitude.

Let $d$ = altitude = 0·87 $a$, nearly;

$$\therefore \qquad a^2 = \frac{d^2}{\cdot 7569},$$

which substituted in (15) gives

$$0{\cdot}72 \frac{\text{R } d^2 b}{12}.$$

Hence the resistance of the maximum trapezoidal beam is that of a rectangular one having the same base and altitude as $\frac{1}{1}\frac{1}{2}$ of 0·72 : $\frac{1}{6}$, or as 360 : 1000.

*Experiments made by M. Starke, with the machine of the Polytechnic Institution of Vienna, upon various Cast Steels made at the Imperial and Royal Foundry at Reichraming in Styria.*

| | Breaking weight per square millimetre. | |
|---|---|---|
| No. 1. Common Steel of Reichraming. | 92·49 kilog. | |
| " " | 83·29 | |
| " " | 85·39 | |
| 2 " | 51·89 | Defect in the fracture. |
| " " | 81·91 | |
| " " | 96·84 | |
| 3 " | 112·42 | |
| " " | 105·32 | |
| " " | 86·44 | |
| 4. English Steel, (known as Huntsman's,) | 84·34 | |
| " " | 86·51 | |
| " " | 76·99 | Blister in surface of rupture. |
| 5. Steel made with Tungsten, | 102·26 | |
| " " | 109·27 | |
| " " | 117·10 | Broke at a section greater than the minimum. |

NOTE.—The kilogramme = 2·2 lbs. The millimetre = 0·0394 inch.

*Bull. Soc. Encour. Indust. Nat.*, May, 1860.

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### *Superheated Steam.*

The readers of the *Journal* have no doubt read much on this subject in the last few years, and there can be no doubt that, if superheated steam is properly used, a saving of fuel may be effected. Many of the statements published, however, have made the success too great. It will be remembered that, a short time since, the *Artizan* published some very flattering accounts of the performance of the English Pacific Mail steamers, whose machinery was put in by Randolph, Elder & Co. The engines had double cylinders, and used *highly superheated steam* (450 to 500 degrees). It is now found that this high heat is very destructive to the engines, injuring the cylinders, pistons, valve faces, and valves. So great has the injury been, that they have commenced to take out and much reduce the number of superheating tubes. B.

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### *Artificial Making of Ice.*

M. Carré takes two iron retorts strong enough to bear a pressure of 8 atmospheres; two mercury-bottles for instance. In one he places a very concentrated solution of ammonia; and then connects it by a tube with the other retort which is empty. A furnace heats the first retort, the second is buried in a vessel containing water at the temperature of

the air. The heat disengages the ammonia from its solution, and it passes over into the cool retort, where the pressure due to its accumulation gradually condenses it into a liquid. The furnace is then withdrawn from the other retort, which is suffered to cool, and as soon as it has cooled sufficiently, the pressure is reduced within it, and at a certain point the ammonia passes abruptly into a gas again, absorbing from the water which surrounds the retort the heat necessary for its evaporation. A part of the water is frozen, and 2½ kilog. (5 lbs.) of ice may thus be obtained. Of course, the operation may be repeated at pleasure. The apparatus, as will be seen, is excessively simple, and is said to be marvellously effective. It is affirmed that the price of ice thus obtained will not exceed 1 centime per kilogramme ($\frac{1}{10}$th of a cent) per lb.—*Cosmos*, December, 1860.

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### *Electric Light. A Beautiful Experiment.*

On the 2d of September a first experiment was made, of illuminating the famous Falls of Schaffhausen on the Rhine, 30 yards in height, by means of five electric lights: the effect is said to have been marvellous; especially when viewed through colored glasses; the waves of the river resembled a sea of fire. It is said that the experiment was instituted at the request of the directors of the Swiss Railroad Company, who propose during the coming year to organize a series of night-fêtes, of which this illumination will be the greatest attraction.

*Cosmos*, September, 1860.

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### *Fire Extinguished by Steam.*

A fire took place on the 22d of November, in the cellars of a candle manufacturer, situated on the *Route d'Italie*, outside the barrier. The engines were of but little value, and to subdue the flames they had recourse to a mode but little in use. The cellar-doors and windows having been hermetically shut, steam was introduced and the fire in a few moments extinguished. By this quick and effectual method, 200 tons of oil which the flames were on the point of reaching were preserved.

*Cosmos*, November, 1860.

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| —— | W. R. Center, | Athens, | " | 4 |
| —— | A. S. and D. Markham, | Monmouth, | " | 11 |
| —— | Mowry & Deppen, | Womelsdorf, | Penna. | 11 |
| —— | J. H. Rankin, | Versailles, | Mo. | 4 |
| ——,—Husking and Shelling | John Wind, | Thomasville, | Ga. | 4 |
| Cotton Cleaners, | J. Ryder and others, | Clinton, | La. | 18 |
| —— Cleaning Machines, | Benjamin Jackson, | Louisville, | Ky. | 11 |
| Coupling for Hose Pipe, | Button & Blake, | Waterford, | N. Y. | 18 |
| Cultivators, | H. M Belden, | Farmington, | Ohio, | 4 |
| —— | Geisinger & Williams, | Montville, | " | 18 |
| —— | Jos. and St. Clair Gum, | Marseilles, | Ill. | 18 |
| —— | Isaac Miers, | Clay Lick, | Ohio, | 18 |
| —— | Benjamin Tinkham, | Cameron, | Ill. | 11 |
| ——,—Cotton, | N. A. H. Goddin, | Wilson, | N. C. | 4 |
| ——,—Seeding | T. A. Galt, | Sterling, | Ill. | 11 |
| Curtain Cords, | T. L. Pye, | City of | N. Y. | 18 |
| —— Fixture, | Harold & Kelty, | Brooklyn, | " | 11 |
| Dentists Crystalline Gold, | A. J. Watts, | Utica, | " | 4 |
| Dumb Waiters, | Andrew Murtaugh, | City of | " | 4 |
| Eave Troughs, | G. M. Selden, | Troy, | " | 8 |
| Ellipsograph, | R. E. Harte, | Marietta, | Ohio, | 4 |
| Envelopes, | J. B. Murray, | City of | N. Y. | 18 |
| Excavators, | J. P. Hayes, | Hennepin, | Ill. | 4 |
| Extension Table, | George Hunzinger, | Brooklyn, | N. Y. | 4 |
| Faucets for Bottles, | Jacob Hiney, | Hartford, | Conn. | 18 |
| Feed Cutters, | G. W. Hathaway, | Tioga, | Penna. | 4 |
| Fertilizers,—Sowing | B. Picquet, | Augusta, | Ga. | 11 |

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|---|---|---|---|---|
| Fire Escapes, . | Claude Sturel, . | City of | N. Y. | 18 |
| Fluid,—Expanding, &c., Elastic | John Jameson, . | Gateshead, | Engl'd, | 18 |
| Foot-scraper and Brush, . | Henry Warren, . | Hoboken, | N. J. | 4 |
| Gas and Water Pipe,—Tapping | J. J. Watson, . | Buffalo, | N. Y. | 11 |
| —— Burner Regulator, . | Wm. Mallerd, . | Bridgeport, | Conn. | 18 |
| Glass Cutters, . | Moses Kleeman, | Columbus, | Ohio, | 18 |
| Gongs,—Striking Mechanism for | S. S. Chandler, . | Chelsea, | Mass. | 4 |
| Grain,—Cleaning . | R. C. Mauck, . | Harrisonburg, | Va. | 18 |
| —— Riddles, . | Anson Rowe, . | Atallissa, | Iowa, | 4 |
| —— Separators, . | F. W. Robinson, | Richmond, | Ind. | 18 |
| Hame Tugs,—Fastening for | J. W. Church, . | Cold Water, | Mich. | 18 |
| Harness Trace, . | Edmund Maher, | City of | N. Y. | 4 |
| Harpoons,—Explosive . | Theodore Briggs, . | Philadelphia, | Penna. | 11 |
| Harrows, . | John Allen, . | Union, | N. Y. | 18 |
| ——,—Rotary . | M. L. Bauder, . | Cleveland, | Ohio, | 4 |
| Harvesters, . | John Blue, . | Covert, | N. Y. | 18 |
| ——,—Cotton . | Apperly & Johnson, . | Memphis, | Tenn. | 11 |
| ——,—Rakes for | S. A. Lindsay, . | Unionville, | Md. | 11 |
| —— . | Adam Pritz, . | Dayton, | Ohio, | 4 |
| Harvesting Machines, | McClintock Young, Jr., | Frederick, | Md. | 18 |
| —— . | J. S. Royce, . | Cuylerville, | N. Y. | 18 |
| ——,—Rakes for | L. P. Brady, . | Mount Joy, | Penna. | 18 |
| Hats,—Shaping . | S. H. Apple and others, | City of | N. Y. | 4 |
| Hogs from Rooting,—Preventing | D. K. Nixon, . | Sandyville, | Ohio, | 18 |
| Horse Collars, . | John Ende, . | Buffalo, | N. Y. | 18 |
| Horses from Carriages,—Detach. | Solomon Kepner, | N. Coventry, | Penna. | 18 |
| Hydraulic Engines, : | Thomas & Hall, . | Beverly, | Va. | 4 |
| Insect Shields for the Head, | John Haven, . | Boston, | Mass. | 4 |
| Lamp Chimneys,—Securing | J. J. Marcy, . | Meriden, | Conn. | 4 |
| Lamps,—Vapor . | J. S. Gray, . | City of | N. Y. | 18 |
| —— . | F. W. Willard, . | " | " | 11 |
| Lathe Dog,—Automatic | A. E. Wenzel, . | " | " | 18 |
| Lock,—Combination . | J. H. Morse, . | Peoria, | Ill. | 4 |
| ——,—Knob . | John Adt, . | Waterbury, | Conn. | 11 |
| Loco. Engines,—Exhaust Pipes | G. W. Lathrop, . | Weedsport, | N. Y. | 18 |
| ——,—Superheat. st'm | James Martin, . | Toronto, | Can. | 4 |
| ——,—Supply. Water | Merritt & Kemplen, . | Woodstock, | Ill. | 4 |
| Looms, . | Andrew Parkinson, | Norwich, | Conn. | 18 |
| Mangle, . | Wm. D. Grimshaw, . | City of | N. Y. | 4 |
| Mattress,—Life-preserving | Louis Bauhoefer, | Philadelphia, | Penna. | 4 |
| Medicated Lotions, . | J. G. Popp, . | Vienna, | Austria, | 4 |
| Millstones,—Dressing | B. D. Tripp, . | Moravia, | N. Y. | 18 |
| Mouldings,—Enameling . | Gabriel Boos, . | City of | " | 18 |
| Mowing Machines, | J. G. Dunham, . | Raritan, | N. J. | 18 |
| Musical Instruments, . | E. D. Bootman, . | Janesville, | Wis. | 18 |
| Oiling Spindles, . | E. N. Steere, . | Providence, | R. I. | 18 |
| Paddle Wheel,—Feathering | Byron Densmore, . | Brockport, | N. Y. | 4 |
| Padlock, . | John North, . | Middletown, | Conn. | 18 |
| Paper,—Folding . | J. S. Gallaher, Jr., . | Washington, | D. C. | 4 |
| —— Folding Machines, | Cyrus Chambers, Jr., | Philadelphia, | Penna. | 18 |
| Parchment,—Vegetable . | Xavier Karcheski, . | City of | N. Y. | 18 |
| Peach Parer and Cutter, | H. St. J. Hilsman, | Madison, | Ga. | 4 |
| Pendulum,—Compensating | George Buchanan, . | Hickory, | Penna. | 4 |
| Pegging Machines, | Parker Wells, . | Middleton, | Mass. | 18 |
| Pens,—Fountain . | Ebenezer Mathers, . | Fairmount, | Va. | 4 |
| —— . | S. A. Skinner, . | W. Berkshire, | Vt. | 18 |
| —— . | G. W. Woolley, . | Philadelphia, | Penna. | 4 |

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| Photographic Cameras, | Simon Wing, | Waterville, | Me. | 4 |
| Planers,—Parts in Rotary | A. J. Kramer, | Marion, | Iowa, | 11 |
| Planing Machines,—Wood | H. D. Stover, | City of | N. Y. | 18 |
| Plough Clevises, | J. S. Hall, | Manchester, | Penna. | 4 |
| Ploughs, | H. H. Baker, | New Market, | N. J. | 11 |
| ——— | Everett Bass, | Pachitta, | Ga. | 4 |
| ——— | J. G. Robinson, | Biddeford, | Me. | 4 |
| ——— | Oliver Sparks, | Shelbina, | Mo. | 11 |
| ——— | Smithwick Whitley, | Tallahassee, | Fla. | 4 |
| ———,—Gang | Jacob Haege, | Shiloh, | Ill. | 18 |
| ———,—Steam | Wm. H. H. Meillen, | Littleton, | N. H. | 11 |
| ——— ——— | John Reynolds, | City of | N. Y. | 18 |
| Pressure Gauge, | C. M. Daboll, | New London, | Conn. | 4 |
| Pumps, | J. B. Johnson, | Boston, | Mass. | 4 |
| Quartz Rock, &c.,—Breaking | S. F. Hodge, | Detroit, | Mich. | 4 |
| ———,—Mills for Crushing | " | " | " | 4 |
| Railroad Car Frames, | T. L. Nickols, | Alexandria, | Va. | 4 |
| ——— Cars,—City | Grice & Long, | City of | N. Y. | 18 |
| ———,—Warming | J. J. Watson and others, | Buffalo, | " | 18 |
| ——— Cross Ties, | R. C. Bailey, | Greensboro, | N. C. | 4 |
| ——— Switches, | Horace Tupper, | Buffalo, | N. Y. | 4 |
| ———,—Turn-outs for Street | " | " | " | 18 |
| Railway Signals, | P. F. Milligan, | Baltimore, | Md. | 18 |
| Rakes for Reaping Machines, | J. R. Byler, | Salisbury t'p, | Penna. | 4 |
| Revolvers, | Smith & Wesson, | Springfield, | Mass. | 18 |
| ——— | Eben F. Starr, | City of | N. Y. | 4 |
| Roofing,—Cement for | J. F. Hammond, | Lynn, | Mass. | 18 |
| Rotary Engine, | J. J. Slocum, | City of | N. Y. | 18 |
| Rovings,—Winding Woolen | J. A. Chapman, | Pequetanuck, | Conn. | 18 |
| Saw Gauge,—Circular | Lysander Wright, | Newark, | N. J. | 18 |
| Sawing Machines,—Cross-cut | S. A. Worthen, | Morrisville, | Vt. | 11 |
| ——— | D. B. Bartholomew, | Lancaster, | Penna. | 11 |
| Saws,—Handles to | E. C. Atkins, | Indianapolis, | Ind. | 18 |
| Scales,—Platform | Jedediah Holcomb, | Brandon, | Vt. | 18 |
| Seeding Machines, | D. and W. W. Beal, | Lester, | Iowa, | 11 |
| ——— ——— | Henry Bell, | Clinton, | Ill. | 11 |
| ——— ——— | Horace Crofoot, | Tawboro, | N. C. | 11 |
| ——— ——— | Naylor & Ward, | Niles towns'p, | Ind. | 4 |
| ——— ——— | J. V. H. Secor, | City of | N. Y. | 11 |
| Seed Planters,—Cotton | R. C. Mash, | Somerville, | Tenn. | 18 |
| ——— ——— | C. A. Rose, | Columbia, | Ala. | 4 |
| Sewing Machines, | J. W. Hardie, | City of | N. Y. | 4 |
| ——— Needles, | Henry Essex, | Haverstraw, | " | 18 |
| Shirred Goods,—Making | Richard Solis, | N. Brunswick, | N. J. | 11 |
| Shirt Bosom Expanders, | S. J. Shaw, | Marlborough, | Mass. | 4 |
| ——— Studs, | C. E. Haskins, | Providence, | R. I. | 18 |
| Shoe Tacks, | J. H. Knight, | Newburyport, | Mass. | 18 |
| Shutter Operator, | John Solan, | Fredericksburg, | Va. | 18 |
| Skirts,—Clasp for Hooped | G. P. Evans, | Malden, | Mass. | 11 |
| ———,—Skeleton | E. G. Atwood, | Derby, | Conn. | 18 |
| ———,—Spiral Hoop | D. G. Rollin, | City of | N. Y. | 4 |
| Smut Machines, | Robert Thompson, | E. Davenport, | Iowa, | 18 |
| Spinning Frames,—Cylinders for | Robert Plews, | Smithfield, | R. I. | 18 |
| Steam Boiler, | B. F. Campbell, | Roxbury, | Mass. | 18 |
| ——— | Samuel Solliday, | Sumneytown, | Penna. | 18 |
| Stove Covers, | John Russell, | Troy, | N. Y. | 18 |
| ——— Pipes, | Levi Bissell, | North Bergen, | " | 18 |
| Stoves,—Gas | J. L. Mahan, | Philadelphia, | Penna. | 18 |
| Straw,—Cutting | Warren Gale, | Chicopee Falls, | Mass. | 18 |
| Sugar,—Tanks for Crystallizing | C. E. Bertrand, | City of | N. Y. | 18 |

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| Sugar-cane Leaf Stripper, | P. P. Mills, | Washington, | Ohio, | 18 |
| Swifts, | Newton Benedict, | Aurelius, | N. Y. | 11 |
| Temples, | J. C. Tilton, | Sanbornton Br. | N. H. | 11 |
| Tenoning Tool, | Oswald Schevenell, | Marion, | Ala. | 11 |
| Thread,—Dressing | Conant & Ives, | Willimantic, | Conn. | 4 |
| ——— | O. and G. Hall, | Willington, | " | 4 |
| Time Registers, | Robert Schone, | City of | N. Y. | 4 |
| Tin Cans,—Wiring | Thomas Evans, | Watkins, | " | 4 |
| Tobacco Cutters, | W. H. Pease, | Dayton, | Ohio, | 18 |
| Tuyere, | C. H. Edwards, | Vergennes, | Vt. | 4 |
| Valve Gear for Steam Engines, | J. R. Jacob, | Elizabethtown, | Ky. | 18 |
| Valves, | John and C. B. Hardick, | Brooklyn, | N. Y. | 4 |
| ——— for Oscillating Engines, | L. W. Langdon, | Northampton, | Mass. | 4 |
| ——— of Boilers,—Safety | Charles Graham, | Scranton, | Penna. | 18 |
| ——— of St'm Eng's,—Operat'g | L. H. Bowman, | Norristown, | Penna. | 18 |
| ———,—Slide | Thomas Mahoney, | Knoxville, | Tenn. | 4 |
| Ventilating Buildings,—Means | S. M. Stone, | New Haven, | Conn. | 18 |
| Wagons,—Road | J. W. Lawrence, | City of | N. Y. | 11 |
| Washing Machine, | D. P. Shope, | Milesburg, | Penna. | 18 |
| ——— | P. D. Van Hoesen, | City of | N. Y. | 11 |
| Watch Ribbons,—Slides for | A. H. Hews, | Cambridgeport, | Mass. | 18 |
| Watches,—Regulating | A. L. Dennison, | Waltham, | " | 11 |
| Water Drawers, | A. A. Hotchkiss, | Monroe City, | Mo. | 11 |
| ——— Elevators, | Taylor & Larned, | Cleveland, | Ohio, | 11 |
| ——— & Conveyors, | J. F. Keller, | Greencastle, | Penna. | 11 |
| ———,—Elevating | Luther Wentworth, | Burlington, | Iowa, | 4 |
| ——— | J. D. Squires, | Cold Spring, | N. Y. | 11 |
| ——— Wheels, | Jud Crissey, | Chatfield, | Minn. | 18 |
| ——— | E. F. M. Fletcher, | Georgia Plains, | Vt. | 18 |
| ——— | Nelson Johnson, | Jasper, | N. Y. | 18 |
| Wrench, | F. W. Kroeber, | Forbestown, | Cal. | 18 |
| ——— | Ezra Ripley, | Troy, | N. Y. | 18 |

ADDITIONAL IMPROVEMENTS.

| | | | | |
|---|---|---|---|---|
| Coupling for Thills to Axles, | James Saddler, | Egremont, | Mass. | 18 |
| Fabrics Incorrodible,—Render'g | T. G. Chase, | Philadelphia, | Penna. | 11 |
| Insects,—Prevent. Depredations | F. G. Johnson, | Brooklyn, | N. Y. | 18 |
| Refrigerators, | Wm. Sims, | City of | " | 4 |
| Washing Machine, | Asbury Wilkinson, | Shelbyville, | Ind. | 4 |

RE-ISSUES.

| | | | | |
|---|---|---|---|---|
| Bedsteads,—Folding (2 pat's) | J. B. Wickersham, | Brooklyn, | N. Y. | 18 |
| Copying Apparatus,—Portable | Wm. Van Anden, | Poughkeepsie, | " | 18 |
| Corn Shellers, | J. J. Johnston, | Allegheny City, | Penna. | 11 |
| Harvesters,—Raking Attachment | W. H. Seymour & others, | Brockport, | N. Y. | 18 |
| Hat Bodies, (2 pat's) | H. A. Burr, | City of | " | 4 |
| Irregular Forms,—Cutting | R. J. Mearcher, | " | " | 18 |
| Paper Pulp,—Grinding | J. Jordan, Jr., and others, | Hartford, | Conn. | 4 |
| Preserve Cans, | Carlton Newman, | Birmingham, | Penna. | 18 |
| Projectiles, | C. T. James, | Providence, | R. I. | 11 |
| Provisions,—Curing | D. E. Somes, | Biddeford, | Me. | 11 |
| Rubber,—Hard | T. J. Mayall, | Roxbury, | Mass. | 11 |
| Seed Planters, (5 pat's) | G. W. Brown, | Galesburg, | Ill. | 11 |
| Steering Apparatuses, | Jesse Reed, | Marshfield, | Mass. | 4 |
| Threshing Machines, | Spencer Moore, | Central Bridge, | N. Y. | 18 |

DESIGNS.

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|---|---|---|---|---|
| Carpet (7 cases), | E. J. Ney, | Lowell, | Mass. | 18 |
| Floor Cloths, | C. T. Meyer, | Boston, | " | 4 |

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| Iron Shutters, | E. H. Brown, | City of | N. Y. | 18 |
| Stove, | Zebulon Hunt, | Hudson, | " | 4 |
| ——— | Smith & Brown, | Philadelphia, | Penna. | 18 |
| Stoves, | Isaac DeZouche, | St. Louis, | Mo. | 4 |
| ———,—Cooking | Jacob Steffe, | Philadelphia, | Penna. | 18 |
| ——————— | C. J. Woolson, | Cleveland, | Ohio, | 4 |
| Stove Plates, | Vedder & Ripley, | Troy, | N. Y. | 18 |
| ——— | Vedder & Sanderson, | " | " | 18 |
| ——— | C. J. Woolson, | Cleveland, | Ohio, | 4 |

## FRANKLIN INSTITUTE.

*Proceedings of the Stated Monthly Meeting, February* 21, 1861.

John C. Cresson, President, in the chair.

John Agnew, Vice President.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

A letter was read from the Board of Arts and Manufactures, Montreal, Canada, transmitting a catalogue of their Exhibition held last Autumn, and a Bronze Medal struck on the opening of the Victoria Bridge by H. R. H. Prince of Wales, Montreal, 1860.

Donations to the Library were received from the Royal Society, the Royal Astronomical Society, the Statistical Society, and the Society of Arts, London; la Société Industrielle de Mulhouse, France; the Oesterreischischen Gewerbe-Veriens, the Oesterreischischen Ingenieurs-Veriens, Vienna, Austria; the Board of Arts and Manufactures and Capt. L. A. Huguet-Latour, Montreal, Canada; the Board of Trade, Detroit, Michigan; the Ohio Mechanics Institute, Cincinnati, Ohio; E. S. Philbrich, Esq., Boston, Mass.; the American Institute, City of New York; the Commissioner of Patents, Washington City, D. C.; W. R. DeWitt, State Librarian, H. G. Leisenring, Esq., and John Heisely, Esq., Harrisburgh, Penna; Wm. Linn Brown, Esq., the Pennsylvania Institution for the Blind, the American Philosophical Society, the North Pennsylvania Railroad Co., the Mine Hill and Schuylkill Haven Railroad Co., Prof. John C. Cresson, and George M. Conarroe, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's statement of the receipts and payments for the month of January was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (4) were proposed, and the candidates proposed at the last meeting (5) duly elected.

The Board of Managers reported that they had organized for the present year by electing Mr. James H. Bryson, Chairman, and Messrs.

Isaac S. Williams and John M. Gries, Curators, and have appointed the following Standing Committees:

| *On Publications.* | *On Instruction.* | *Managers Sinking Fund and Finance.* |
|---|---|---|
| John C. Cresson, | John F. Frazer, | Frederick Fraley, |
| B. H. Bartol, | Frederick Fraley, | Samuel V. Merrick, |
| J. Vaughan Merrick, | Isaac B. Garrigues, | Evans Rogers, |
| Fairman Rogers, | Alan Wood, | John F. Frazer, |
| Washington Jones. | George Erety. | George Erety. |

The Standing Committees for the ensuing year were appointed by the President, and approved as follows:

| *On the Library.* | *On Cabinet of Models.* | *On Cabinet of Minerals.* |
|---|---|---|
| John Allen, | James Agnew, | Isaac H. Conrad, |
| Henry Ames, | Joseph Alexander, | Wm. T. W. Dickeson, |
| James H. Cresson, | William B. Bement, | John F. Frazer, |
| George M. Conarroe, | James Fraiser, | Emile Geyelin, |
| George Erety, | George W. Hubbard, | Isaac B. Garrigues, |
| John Ferguson, | Henry W. Hook, | John L. LeConte, |
| Raper Hoskins, | John L. Perkins, | B. Howard Rand, |
| James T. Lukens, | Coleman Sellers, | Robert E. Rogers, |
| Samuel Middleton, | John A. Scot, | Percival Roberts, |
| John S. Sleep. | Henry J. White. | John C. Trautwine. |

| *On Cab. of Arts & Manuf.* | *On Exhibitions.* | *On Meetings.* |
|---|---|---|
| Daniel Allen, | John E. Addicks, | William B. Atkinson, |
| James C. Booth, | John Agnew, | Robert Briggs, |
| Thomas Bickerton, | James H. Bryson, | William H. Brown, |
| Henry Bower, | James H. Cresson, | Charles S. Close, |
| John H. Burgin, | William A. Drown, | James Dougherty, |
| Robert C. Cornelius, | John M. Gries, | Thomas M. Drysdale, |
| Charles G. Crane, | Edwin Greble, | Henry Howson, |
| David M. Hogan, | William Harris, | Washington Jones, |
| Henry J. Taylor, | Thomas S. Stewart, | B. Howard Rand, |
| Henry P. Taylor. | Isaac S. Williams. | John E. Wootten. |

*On Meteorology.*

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|---|---|
| Chas. M. Cresson, | J. Aitken Meigs, |
| George K. Crozer, | Benjamin V. Marsh, |
| William A. Drown, Jr., | Fairman Rogers, |
| John F. Frazer, | James S. Whitney, |
| Jas. A. Kirkpatrick, | Thomas J. Weygandt. |

Some cakes of Bentrinck's "kindling" were laid upon the table. They are composed of pine saw-dust and resin pressed in moulds whilst in a warm semi-fluid mass, and then permitted to harden. One cake, of about two inches square by one inch thick, is said to be sufficient to start a fire of wood.

Specimens of scale one and one-quarter inches thick, taken from the boiler of a steamer plying between New York and New Orleans, were shown as remarkable for thickness.

Mr. Samuel Solliday, of Sumneytown, Penna., sent a model of his safety casing for marine boilers. It is to be formed of very strong materials, and completely surrounds the boiler except at the top, which is closed by a light lid to exclude rain. Should an explosion take place, it is intended to be compelled to expend itself in an upward direction and prevent damage to the people or hull of the vessel.

Messrs. W. Wrightson and J. J. Thibault submitted to the meeting for examination a number of specimens of ores and minerals, when Mr. Wrightson made the following remarks:

The subject of the Silver Mines of Arizona was briefly presented to the meeting. Arizona extends from the Colorado river to the western boundary of Texas, and from the boundary of Mexico to the 34th parallel of north latitude. The portion between the Mexican boundary line and the Gila river is better known as the Gadsden purchase, and is the seat of all the improvements thus far made in Arizona. In an agricultural point of view this territory is comparatively of little value. Its arable land is confined to the narrow valleys of the streams where the banks are sufficiently level to admit of artificial irrigation by means of acequias or ditches. The most extensive and fertile of these valleys is that of the Rio Grande, in the neighborhood of the town of Mesilla, and is generally known as the Mesilla valley. It is about 20 miles in length and 10 in width. Its soil is exceedingly fertile and produces fine crops of corn and wheat. The waters of the river are taken in a large acequia at the northern extremity of this valley, and carried around the foot of the mountains and thence distributed in smaller acequias over the whole plain.

Viewed from the mountains on the west, this valley presents a beautiful appearance. Its level plain covered with rich vegetation, its acequias spread over its surface like a silver net, the Rio Grande flowing in silent majesty in the distance, towns of Mesilla and Las Cruces, and the houses of the farmers scattered here and there in the scene, while the whole landscape is shut in by the majestic range of the Organ mountains rising in almost perpendicular cliffs to the east. Next in importance to this are the valleys of the Sonoita and Santa Cruz, which include the settlements near Fort Buchanan and the towns of Tubac and Tucson. In addition to these are the valleys of the Mimbres, the San Pedro, and the Gila rivers; all of which contain some arable land. To the north of the Gila are said to be many fertile valleys now cultivated by the Indians. The whole surface of Arizona is well grassed, and it is possible that it will at some time be a grazing country.

Arizona derives its principal importance from its being a mineral region, and from the fact that the passes over the Rocky Mountains are lower here and more favorable to the construction of a railroad across the continent than on any other route. There seems to be a grand depression across the whole continent on the line of the Gulf of Mexico and the Gulf of California at the south, and the line of the great lakes at the north. This southern route through Arizona is the route of the 32d parallel, and affords both the shortest line and lowest passes and most favorable climate for the Pacific route. The mineral resources of Arizona are but beginning to be developed. The pioneers in this movement were a small exploring party sent out from Cincinnati in the spring of 1856. This party discovered and opened the Heintzelman mine, 20 miles west of Tubac, and are still working this mine. It is a vein of the grey sulphuret of silver and copper, yielding ores varying in richness from $ 100 to several thousand dollars per

ton; the average being $200 per ton. Near this mine are the Longorenia mine, the Arenilla mine, the Cahuabi mine, and a group of old mines on the Arivaca Ranche, yielding silver, copper, and lead. To the west of this group are the Ajo copper mines yielding ores from 60 to 80 per cent. of copper. To the east of the Heintzelman group are the Santa Rita mines opened by the Santa Rita Co. of Cincinnati. This group includes the Salero, the Ojero, and the Bustillo mines, which were worked extensively by the Spaniards previous to the Apache war, and the Crystal, the Gila, the Encarnacion, the Cazador, the Buena Ventura, the Tajito mines, which have been opened by this company. The mineral deposits of the Santa Rita are remarkable for the bold and extensive character of the veins. The mountain seems to have been tossed by some internal convulsion which shook and disturbed its whole mass, in some places filling the fissures with a dense crystalline mass of mineral, and in others depositing the metallic salts like soot in chimneys to the infernal regions. The Crystal mine is a dense compact vein of sulphuret of lead in steel grain crystals 20 inches in thickness, yielding 60 per cent. of lead, and having a small ley of silver. This vein outcrops on the surface nearly a mile in length. The Gila, Buena Ventura, and the Tajito mines are veins of the grey sulpuret of silver and copper, with threads of galena in large crystals. They are 5½ feet and 8 feet in width, and at the lower workings begin to yield native silver. Next, east from the group of the Santa Rita, are the mines of the Santa Cruz Mountains, including the Patagonia, the Empire, the San Antonio, the Trench, and others, yielding lead and silver. Eastward from these, at a distance not exceeding 30 miles, is another group of mines, yielding silver, copper, and lead, which is said to have given importance to the old Ranche of Babacomeri many years ago. They are not now worked. Passing eastward over an interval of 200 miles, in which veins of silver and copper ores and gold-bearing quartz are known to exist but are not yet taken up, are the Mimbres mine, including the Santa Rita del Cobre, the Hanover copper mines, the San José gold mines, the gold placers of the Mimbres, and several veins of silver and lead. The copper mines yield ores varying from 50 per cent. to native copper in great abundance. The copper of these mines is transported in wagons 1200 miles to the coast of the Gulf of Mexico, and thence by vessel to New York, at a profit on even this expensive transportation. The gold mines were worked originally by the Spaniards, but were abandoned at the time of the Apache war for want of better protection than was then afforded. They compare favorably with the best paying mines of California. Farther to the east, in the Organ mountains which line the valley of the Rio Grande, is the Stevenson mine, so called from Mr. Stevenson, of El Paso, who first opened this mine. It is a large bold vein of argentiferous galena, and is now worked by a company organized under the general laws of New York. In the same locality are the Santa Clara, the Santa Isabella, and other mines not now worked, but which are capable of yielding large masses of ore.

To the north of this chain of mines which have been here pointed

out, and which stretch for a space of 400 miles along the parallel of 32° north latitude, in the valley of the Gila river and near the meridian of 111° west longitude, is the Maricopa copper mine discovered by Col. A. B. Gray. It is a wide vein of the grey sulphuret of copper, and promises to be a mine of great importance; while all along the valley of the Gila are said to be deposits of gold-bearing quartz.

The specimens of ore exhibited to the Society were mainly from the Santa Rita and the Mimbres mines. They consisted of steel grained galena from the Crystal mine, Fahl ores from the Gila, the Buena Ventura, the Tajito mines; sulphuret of silver and copper from the Heintzelman mine; galena from the Bustillo mine; sulphuret and carbonate of copper and native copper from the Mimbres mines, and native gold and gold-bearing rock and dirt from the San José mine.

The attention of the Society was called to the commercial wants of Arizona, and the feasibility of a railroad route from Guamas or Port Lobos, on the Gulf of California, to Tubac, and thence by the route of the 32d parallel to the Rio Grande. The distance of Lobos to Tubac is 160 miles, over a route that is moderately level, presenting easy gradients and curves. The business to be done by such a road would be the transportation of ores and metals to the coast and return freight of provisions and merchandise to the mines.

The surface of the country is mostly gently rolling swells, the mountains rising abruptly and precipitously in small detached ranges rather than in continuous chains, thus affording an opportunity of winding around their bases. The prevailing rock is trap, and the soil hard gravel. In the absence of a railroad, it was thought wagons propelled by steam could be successfully adopted, the roads possessing all the requisites of hard surface, gentle ascents, and long stretches of straight lines.

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## METEOROLOGY.

For the Journal of the Franklin Institute.

*The Meteorology of Philadelphia.* By JAMES A. KIRKPATRICK, A.M.

JANUARY.—It will be seen by the accompanying table, that during the month of January of this year, the wind was more northerly than usual; the temperature and the force of vapor were lower, while the pressure of the atmosphere, the relative humidity, the amount of rain, and the number of rainy days were greater than usual.

The warmest day of the month was the 7th, of which the mean temperature was 41·7°, but the highest temperature (49½°) was reached on the 19th. The coldest day was the 13th, when the temperature fell to 1°, the mean for the day being 7·8°. It is said that in the western part of the city, about five miles west of the Schuylkill, the mercury fell to 6 degrees below zero on the morning of the 13th. The range for the month was 48½°.

The temperature was below the freezing point on 23 days of the month, though it rose above that point in the afternoon of every day

except six, namely, from the 11th to the 14th inclusive, and on the 23d and 31st.

The changes of temperature were less than usual for January, the mean daily range being less than six degrees, the average for ten years being a little more than six and three-quarters. The daily oscillation of temperature was three degrees less than in January, 1860, though it was only about a quarter of a degree less than the average for the month for ten years.

The pressure of the atmosphere was greatest (30·526 inches) on the morning of the 23d, and least (29·460) on the afternoon of the 16th; range for the month, 1·066 inches. The mean daily range, or average of changes in pressure, was considerably—that is, two-hundredths of an inch—more than usual, and eight-hundredths of an inch more than in the same month of last year.

Snow fell on eight days of the month, to the aggregate depth of about twelve inches. Between 9 and 10 A. M. of the 24th, the flakes of snow falling were very large, many of them being two inches in diameter, and so close to each other that for some time it was impossible to distinguish objects at the distance of one hundred yards.

There were nine days on which the sky was entirely covered with clouds, and four days clear or free from clouds at the hours of observation.

*A Comparison of some of the Meteorological Phenomena of* JANUARY, 1861, *with those of January,* 1860, *and of the same month for ten years, at Philadelphia.*

| | Jan., 1861. | Jan., 1860. | Jan., 10 years. |
|---|---|---|---|
| Thermometer.—Highest, | 49·5° | 58·0° | 62·0° |
| " Lowest, | 1·0 | 3.5 | —5·5 |
| " Daily oscillation, | 11·61 | 14·80 | 11·83 |
| " Mean daily range, | 5·98 | 6·50 | 6·78 |
| " Means at 7 A. M., | 27·67 | 28·89 | 27·29 |
| " " 2 P. M., | 34·34 | 38·37 | 35·09 |
| " " 9 P. M., | 30·90 | 32·97 | 30·81 |
| " " for the month, | 30·97 | 33·41 | 31·06 |
| Barometer.—Highest, | 30·526 in. | 30·399 in. | 30·704 in. |
| " Lowest, | 29·460 | 29·593 | 28·941 |
| " Mean daily range, | ·229 | ·159 | ·208 |
| " Means at 7 A. M., | 29·991 | 29 970 | 29·979 |
| " " 2 P. M., | 29 953 | 29·915 | 29 941 |
| " " 9 P. M., | 29·968 | 29·938 | 29 965 |
| " " for the month, | 29·971 | 29·941 | 29·962 |
| Force of Vapor.—Means at 7 A. M., | ·128 in. | ·136 in. | ·133 in. |
| " " " 2 P. M., | ·144 | ·144 | ·153 |
| " " " 9 P. M., | ·145 | ·143 | ·146 |
| Relative Humidity.—Means at 7 A. M., | 80 per ct. | 80 per ct. | 80 per ct. |
| " " " 2 P. M., | 72 | 61 | 69 |
| " " " 9 P. M., | 81 | 73 | 77 |
| Rain and melted snow, | 4·620 in. | 3·351 in | 3·101 in. |
| No. of days on which rain or snow fell | 13 | 8 | 10 |
| Prevailing winds, | s.52°12′w·375 | s.89°9′ w ·402 | s.63°57′w·343 |

*Abstract of Meteorological Observations for December, 1860; made in Philadelphia, Franklin, and Somerset Counties, Pennsylvania, for the Committee on Meteorology of the Franklin Institute.*

| | Philadelphia.—Lat. 39° 57′ 28″ N. Long. 75° 10′ 28″ W. Height above the sea 50 feet. Prof. J. A. Kirkpatrick, Observer. | | | | | | | | Chambersburg, Franklin Co. Lat. 39° 58′ N. Long. 77° 45′ W. Height 618 ft. Wm. Heyser, Jr., Observer. | | | | | | | Somerset, Somerset Co. Lat. 40° N. Long. 79° 3′ W. Height 2195 feet. Geo. Mowry, Observer. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1860. | Barometer. | | Thermometer. | | | Force of vapor. | Relative humidity. | Rain and snow. | Prevail'g winds. | Barom | Thermom. | | Force of vapor. | Relative humidity. | Rain and snow. | Prevail'g winds. | Barom | Thermom. | | Force of vapor. | Relative humidity. | Rain and snow. | Prevail'g winds. |
| Dec. | Mean. | Mean daily range. | Mean. | Daily oscillation. | Mean daily range. | 2 P.M. | 2 P.M. | | | Mean. | Mean. | Mean daily range. | 2 P.M. | 2 P.M. | | | Mean. | Mean. | Mean daily range. | 2 P.M. | 2 P.M | | |
| | Inch. | Inch. | ° | ° | ° | Inch. | Per ct. | Inches. | Direc. | Inch. | ° | ° | Inch. | Per ct | Inch. | Direc. | Inch. | ° | ° | Inch. | Per ct. | Inch. | Direc. |
| 1 | 29·418 | ·109 | 34·2 | 18 | 6·7 | ·100 | 51 | | N W. | 28·835 | 29·0 | 11·7 | ·078 | 41 | | W. | 27·231 | 20·7 | 4·7 | ·116 | 86 | | W. |
| 2 | 29·618 | ·200 | 33·5 | 10 | 3·7 | ·134 | 64 | | W. | 29·084 | 30·3 | 3·3 | ·067 | 34 | | W. | 27·457 | 21·3 | 3·3 | ·099 | 79 | | W. |
| 3 | 29·818 | ·200 | 34·3 | 16 | 1·5 | ·108 | 45 | | N W. | 29·221 | 34·0 | 3·7 | ·050 | 23 | | W. | 27·546 | 27·3 | 6·0 | ·175 | 89 | | W. |
| 4 | 29·596 | ·222 | 33·7 | 7 | 4·0 | ·183 | 90 | 0·200 | (var.) | 29·012 | 31·0 | 3·0 | ·166 | 79 | 0·200 | (var.) | 27·325 | 28·7 | 2·0 | ·190 | 95 | 0·126 | (var.) |
| ☾ 5 | 29·659 | ·139 | 32·0 | 14 | 3·7 | ·083 | 38 | | W. | 29·006 | 32·0 | 2·3 | ·166 | 55 | | (var.) | 27·358 | 25·0 | 4·0 | ·140 | 88 | 0·149 | W. |
| 6 | 29·705 | ·046 | 33·0 | 13 | 1·7 | ·127 | 60 | | W. | 29·050 | 32·0 | 2·0 | ·067 | 34 | | W. | 27·361 | 25·0 | 3·0 | ·128 | 81 | | W. |
| 7 | 29·857 | ·151 | 36·7 | 10 | 3·7 | ·155 | 60 | | S W. | 29·199 | 37·3 | 5·3 | ·156 | 58 | | W. | 27·558 | 33·0 | 8·0 | ·152 | 64 | | W. |
| 8 | 29·971 | ·114 | 34·2 | 5 | 3·8 | ·183 | 90 | 0·574 | N E. | 29·309 | 39·0 | 1·7 | ·103 | 33 | 0·200 | N E. | 27·040 | 33·7 | 2·7 | ·177 | 85 | 0·332 | E. |
| 9 | 30·134 | ·163 | 29·8 | 8 | 4·3 | ·125 | 65 | | N. | 29·519 | 34·7 | 4·3 | ·165 | 72 | | (var.) | 27·823 | 30·0 | 3·7 | ·142 | 69 | | E. |
| 10 | 29·631 | ·523 | 36·0 | 14 | 6·2 | ·207 | 90 | 0·535 | (var.) | 28·902 | 39·0 | 4·3 | ·191 | 82 | 0·732 | (var.) | 27·250 | 28·0 | 8·0 | ·281 | 95 | 1·104 | (var.) |
| 11 | 29·712 | ·277 | 36·0 | 12 | 6·7 | ·180 | 85 | 0·014 | (var.) | 29·110 | 34·0 | 5·7 | ·103 | 45 | | W. | 27·489 | 26·3 | 11·7 | ·147 | 88 | 0·181 | W. |
| ● 12 | 29·705 | ·122 | 34·0 | 12 | 5·3 | ·129 | 54 | | S W. | 29·018 | 33·0 | 4·3 | ·166 | 72 | | W. | 27·344 | 26·7 | 4·3 | ·154 | 84 | | W. |
| 13 | 29·742 | ·082 | 33·3 | 17 | 4·0 | ·115 | 47 | | W. | 29·152 | 30·7 | 4·3 | ·089 | 38 | | W. | 27·476 | 22·7 | 4·0 | ·095 | 54 | | W. |
| 14 | 30·300 | ·558 | 19·0 | 13 | 14·3 | ·056 | 45 | | N W. | 29·659 | 21·0 | 9·0 | ·025 | 24 | | W. | 27·911 | 14·3 | 8·3 | ·062 | 48 | | (var.) |
| 15 | 30·203 | ·110 | 17·3 | 6¼ | 3·7 | ·070 | 68 | | N E. | 29·688 | 18·3 | 3·3 | ·085 | 72 | 0·050 | W. | 27·856 | 19·0 | 4·7 | ·115 | 75 | | S S E. |
| 16 | 30·189 | ·104 | 25·8 | 20½ | 8·5 | ·106 | 55 | | S W. | 29·561 | 20·0 | 8·3 | ·113 | 67 | | (var.) | 27·843 | 30·7 | 11·7 | ·168 | 65 | | W S W |
| 17 | 30·217 | ·049 | 33·5 | 19 | 7·7 | ·130 | 51 | | (var.) | 29·534 | 30·3 | 10·3 | ·126 | 49 | | (var.) | 27·860 | 31·3 | 9·7 | ·133 | 50 | | ? |
| 18 | 30·325 | ·108 | 30·3 | 12 | 4·5 | ·135 | 61 | | (var.) | 29·651 | 31·3 | 5·7 | ·121 | 62 | | N E. | 27·867 | 32·0 | 4·7 | ·156 | 62 | | S E. |
| 19 | 30·021 | ·304 | 35·3 | 15 | 5·0 | ·198 | 90 | 0·880 | N E. | 29·349 | 28·7 | 2·7 | ·124 | 77 | 1·157 | N E. | 27·585 | 32·3 | 3·0 | ·181 | 94 | 0·746 | S E. |
| ▷ 20 | 29·556 | ·665 | 42·7 | 11 | 7·3 | ·234 | 91 | | S W. | 28·725 | 38·7 | 10·0 | ·181 | 73 | | W. | 27·115 | 37·0 | 4·7 | ·216 | 91 | 0·091 | W. |
| 21 | 29·658 | ·302 | 41·0 | 12 | 5·0 | ·166 | 53 | | W. | 28·968 | 38·3 | 2·3 | ·164 | 59 | | N E. | 27·274 | 36·7 | 2·3 | ·203 | 82 | | W. |
| 22 | 29·607 | ·224 | 38·8 | 15 | 5·5 | ·170 | 65 | 0·243 | (var.) | 29·021 | 33·7 | 7·3 | ·091 | 45 | | W. | 27·475 | 24·0 | 12·7 | ·110 | 86 | | W N W |
| 23 | 30·001 | ·393 | 28·7 | 9 | 10·2 | ·150 | 79 | | N W. | 29·334 | 28·7 | 5·0 | ·090 | 59 | | W. | 27·709 | 23·0 | 5·0 | ·127 | 76 | | N W. |
| 24 | 30·092 | ·091 | 26·8 | 9 | 1·8 | ·075 | 45 | | N W. | 29·478 | 24·7 | 4·0 | ·160 | 36 | | W. | 27·840 | 21·3 | 4·3 | ·071 | 49 | | (var.) |
| 25 | 29·914 | ·178 | 29·0 | 12 | 2·2 | ·154 | 79 | | W N W | 29·299 | 28·7 | 4·0 | ·130 | 78 | | (var.) | 27·666 | 28·7 | 7·3 | ·186 | 81 | 0·173 | (var.) |
| 26 | 30·091 | ·176 | 31·0 | 11 | 2·0 | ·141 | 69 | | N W. | 29·508 | 31·0 | 2·3 | ·085 | 43 | | W. | 27·939 | 23·0 | 5·7 | ·097 | 67 | | W N W |
| ○ 27 | 30·220 | ·129 | 32·0 | 11 | 1·0 | ·127 | 60 | | N N W | 29·636 | 32·3 | 2·0 | ·166 | 55 | | W. | 28·029 | 25·3 | 2·3 | ·121 | 75 | | W N W |
| 28 | 30·333 | ·113 | 30·3 | 7½ | 1·7 | ·138 | 70 | | (var.) | 29·677 | 31·3 | 1·0 | ·103 | 52 | | E. | 28·099 | 26·0 | 2·7 | ·155 | 79 | | E. |
| 29 | 30·345 | ·040 | 31·5 | 9 | 1·5 | ·138 | 70 | | (var.) | 29·660 | 31·7 | 2·3 | ·168 | 89 | | N E. | 27·962 | 24·7 | 4·0 | ·109 | 74 | | E S E. |
| 30 | 30·228 | ·117 | 38·3 | 11 | 6·8 | ·198 | 74 | 0·855 | N E. | 29·567 | 33·7 | 1·7 | ·191 | 90 | 0·600 | N W. | 27·977 | 29·3 | 5·3 | ·191 | 99 | 0·421 | ? |
| 31 | 30·247 | ·076 | 28·0 | 18 | 10·3 | ·123 | 77 | | N W. | 29·638 | 22·0 | 11·7 | ·113 | 67 | | W. | 27·932 | 19·0 | 11·0 | ·108 | 65 | | W. |
| Means | 29·936 | ·196 | 32·3 | 12 | 5·0 | ·140 | 66 | 3·301 | N 52° W | 29·207 | 31·0 | 4·8 | ·115 | 57 | 2·939 | N 47° W | 27·636 | 27·0 | 5·3 | ·145 | 76 | 3·333 | S 87° W |